WEAPON SYSTEM ENVIRONMENTAL
LIFE CYCLE COST
METHODOLOGIES AND MODELS

THESIS

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William H. Kale III

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List of Acronyms

ACAT – Acquisition Category
ACEIT – Automated Cost Estimation Integration Tool
AF - Air Force
AFLC – Air Force Logistics Command
AFMC – Air Force Material Command
AFSC – Air Force Systems Command
ASC – Aeronautical Systems Center
AFESHCAG – Air Force Environmental, Safety, and Health Cost Analysis Guide
AMARC – Aerospace Maintenance and Regeneration Center
CAE – Component Acquisition Executive
CAIG – Cost Analysis Improvement Group
CCA – Component Cost Analysis
CE – Concept Exploration
CER – Cost Estimating Relationship
CERCLA – Comprehensive Environmental Response, Compensation and Liability Act
CES – Cost Element Structure
DAE – Department Acquisition Executive
D&D – Demilitarization and Disposal
DoD – Department of Defense
DUSD(ES) – Deputy Undersecretary of Defense for Environmental Security
EA – Environmental Accounting
ECAM – Environmental Cost Analysis Methodology
ECHO – Environmental Cost of Hazardous Operations
ELCC – Environmental Life Cycle Cost
EMD – Engineering and Manufacturing Development
EO - Executive Order
EPA – Environmental Protection Agency
ESH – Environmental, Safety, and Health
ESTCP – Environmental Security Technology Certification Program
FAR – Federal Acquisition Regulation
FCA – Full Cost Accounting
FM - Financial Management
GAO – General Accounting Office
HTR – Hazardous, Toxic, and Radiological
ICE – Independent Cost Estimate
IPR – In Progress Review
LCC – Life Cycle Cost
JSF – Joint Strike Fighter
MAJCOM – Major Command

MDA – Major Decision Authority
MDAP – Major Defense Acquisition Program
MILCON – Military Construction
MILPERS – Military Personnel
NAVDEP – Naval Depot
NAWCAD – Naval Air Warfare Center Aircraft Division
NEPA – National Environmental Policy Act
NFESC – Naval Facilities Engineering Service Center
OMB – Office of Management and Budget
O&M – Operations and Maintenance
O&S – Operation and Support
PDRR – Program Definition and Risk Reduction
PEO – Program Executive Officer
PESHE – Programmatic Environmental, Safety, and Health Evaluation
PM – Program Manager
POE – Program Office Estimate
QER – Quantity Estimating Relationship
RCRA – Resource Conservation and Recovery Act
RDT&E – Research, Development, Testing, and Evaluation
RFP – Request for Proposal
SM – Single Manager
TCA – Total Cost Assessment
USACEAC – United States Army Cost and Economic Analysis Center
USAEC – United States Army Environmental Center
WBS – Work Breakdown Structure

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Abstract

Major Defense Acquisition Programs (MDAP) cost billions of dollars and have 30 to 50 year life spans. Numerous (federal, state, etc.) laws, Environmental Protection Agency (EPA) regulations, and Executive Orders (EO) have driven DoD to develop and implement significant environmental policies within the past ten to fifteen years. Congressional mandate now requires each MDAP to evaluate its environmental life cycle cost (ELCC) to minimize these costs. This research focuses on the current methodologies and models used to predict and calculate the ELCC of a MDAP.

This thesis analyzed the difficulties associated with using ELCC methodologies and models and examined several case studies of organizations that have used ELCC methodologies and models. Environmental cost categories from three DoD organizations were analyzed and benchmarked to develop a standardized work breakdown structure (WBS) for all MDAP. A set of criteria was developed to evaluate ELCC methodologies and models and then applied to three existing DoD ELCC methodologies and models (Army ELCC Methodology, Navy ELCC Model, and National Defense Center of Environmental Excellence Environmental Cost Analysis Methodology).

A recommendation is provided to the Deputy Undersecretary of Defense for Environmental Security to develop a new foundation for MDAP by adopting the three existing DoD ELCC methodologies and models and the standardized environmental WBS. Finally, suggestions are provided to help MDAP overcome common difficulties associated with the implementation and use of ELCC methodologies and models.

WEAPON SYSTEM ENVIRONMENTAL LIFE CYCLE COST

METHODOLOGIES AND MODELS

I. Introduction

1.1 Background

The Department of Defense (DoD) has numerous weapon system programs that cost billions of dollars and span a period of 30 to 50 years. Numerous (federal, state, local, and international) laws, Environmental Protection Agency (EPA) regulations, and Executive Orders (EO) have driven DoD to develop and implement significant environmental policies within the past 10 to 15 years that have significantly affected the weapon system acquisition process. During the same timeframe, DoD has paid expensive environmental compliance and cleanup costs because their major weapon systems contained and dispensed numerous environmental hazards. In order to help mitigate these problems, each weapon system program is required to conduct a Programmatic Environmental, Safety, and Health Evaluation (PESHE) and calculate their environmental life cycle cost (ELCC). The following paragraphs introduce the nuances of life cycle costing, life cycle cost (LCC) models, ELCC, and ELCC methodologies and models. (7, 1-6)

Life cycle costing tracks and evaluates the total cost of a weapon system throughout its entire acquisition process (research and development, operation and support, etc.). DoD recognized the importance of LCC during the 1960s when numerous weapon systems required unplanned funding during the operation and support phase.

DoD started to incorporate the LCC concept into acquisition programs in the early 1970s, and it was completely institutionalized into acquisition programs during the 1980s. LCC is considered an integral part of the acquisition process today. (45, 9)

Over the past 30 years, cost models have played a large role in life cycle costing. Cost models were developed to track and evaluate different aspects of the LCC of weapon system programs. Currently, DoD has several different life cycle cost models that can be used for a multitude of different applications. The major limitations of cost models are the inability to track individual cost elements (e.g., environmental costs), limited data availability, and overall complexity. (45, 32-34)

Environmental life cycle costing has gradually gained importance over the past 30 years as federal, state, local, and international legislatures passed more stringent environmental legislation every year. In the 1970s and 1980s, private industry was the first to start environmental life cycle costing when they realized that removing pollutants from their products would reduce their overall cost and increase profit in the future (40, 3). Over the past 10 years, DoD has partially embraced the concepts of ELCC. For example, the Air Force (AF) pollution prevention program normally requires environmental efforts to be evaluated based on only a short payback period (usually 3 to 5 years) and analyzes only a small portion of the weapon system (i.e., one material, chemical, or process) (9). The AF pollution prevention program has been successful, but does not take into account all associated environmental costs (e.g., medical, safety, liability, etc.) because of the lack of environmental cost data, complexity of weapon systems, and shortage of resources (manpower and money). (47)

In more recent efforts, the EPA has spearheaded the development of environmental life cycle costing (also know as Total Cost Assessment (TCA)). Numerous publications, case studies, and models have been made available for different government and private organizations to use to evaluate ELCC. Most of these products are excellent tools; however, none of them is robust enough to evaluate the ELCC of a weapon system program. These models tend to track only some environmental costs (e.g., effects of hazardous materials and waste) or processes (e.g., electroplating, power production, etc.) and do not evaluate the entire weapon system (e.g., Joint Strike Fighter (JSF), F-16, A-10, etc.). DoD requires ELCC models that can handle the complexity of a weapon system (e.g., numerous chemicals, materials, processes, hazards, wastes, etc.) and for which the appropriate environmental cost data are readily available.

1.2 Problem Statement

DoD needs to have the ability to predict and document environmental life cycle costs throughout the weapon system acquisition process so better strategies can be developed that focus on reducing the total ownership cost. This will also accommodate the evaluation of the environmental cost of existing and new technologies and will enable the weapon system program manager to make more informed decisions (about different materials, processes, etc.) earlier in the program, when the changes have the greatest impact and least cost.

1.3 Research Objectives and Questions

The objective of this research is to provide DoD weapon system program managers insight on the capabilities and shortcomings of ELCC methodologies and models. With this knowledge, program managers will be able to adopt or develop an ELCC methodology or model that accurately predicts and documents the ELCC of their program or evaluates different alternatives for their program. The following research questions will be answered:

1. *What are common difficulties associated with ELCC methodologies and models?*
2. *Should weapon system program managers calculate their total ELCC?*
3. *What costs should weapon system program managers incorporate into their ELCC estimate?*
4. *What are the capabilities and shortcomings of current DoD ELCC methodologies and models?*
5. *What new DoD policies or guidelines should be implemented to assist weapon system program managers in using an ELCC methodology or model?*
6. *How should a weapon system program manager select or use an ELCC methodology or model?*

1.4 Thesis Overview

The rest of this thesis is divided into the following four chapters: background, methodology, analysis, and conclusions. The background chapter presents information on the impact of environmental costs to DoD; current DoD acquisition, environmental, and financial procedures; and existing DoD ELCC methodologies and models. The methodology chapter lays out procedures to investigate the importance of ELCC and develops assessment criteria to evaluate environmental cost categories and ELCC

methodologies and models. The analysis chapter analyzes the importance of implementing an ELCC methodology for DoD, develops standardized environmental cost categories for DoD, and evaluates three existing DoD ELCC methodologies and models. Finally, the conclusion chapter provides a summary, develops a new foundation to implement and use ELCC methodologies, lists the shortcomings and limitations of this work, and describes areas for future research.

II. Weapon System Environmental Life Cycle Cost Background

2.1 Introduction

Determining the Environmental Life Cycle Cost (ELCC) of a weapon system is complex and complicated. To calculate the ELCC, one must understand the phases of the weapon system acquisition process, applicable environmental regulations, and appropriate cost accounting information. This requires a broad base of knowledge in three separate military professions: acquisition, civil engineering (environmental), and financial management. This chapter provides necessary background knowledge related to calculating the ELCC of a weapon system.

This chapter is divided into five sections. The first section of this chapter will provide a brief background on the impact of environmental costs to the Department of Defense (DoD). The next three sections will summarize the weapon system acquisition process, environmental requirements, and cost information. The final section will review current ELCC methodologies and models, discuss their purpose and uses, examine methodology and model evaluation techniques, and analyze the difficulties of using or adopting an ELCC methodology and model.

2.2 Background

Environmental costs are normally viewed as a minimal part of the initial acquisition costs of a new weapon system like the Joint Strike Fighter (JSF), but they can be a significant cost when viewed over the life cycle of a system. The DoD Inspector General has estimated that more than 80 percent of the hazardous wastes generated by

DoD are related to industrial wastes generated by the producing, operating, and maintaining DoD weapon systems. Industry experience has also shown that the average ratio of cost for the use of a hazardous material compared to handling, treating, and disposing of the waste generated by the hazardous material is 1:80. The General Accounting Office (GAO) has estimated that DoD will eventually spend almost $400 billion to finish cleaning up its environmentally hazardous sites from past practices. To understand and develop effective strategies to avoid or reduce these environmental costs, weapon system programs need to account for their ELCC during the entire acquisition life cycle. (7, 4-5)

For the past 8 years, the environmental budget for DoD was approximately $4.8 Billion a year. This means that DoD spends around 1.5% of its annual budget ($267.2 Billion) on environmental requirements instead of on other mission critical needs. Table 2-1 and Figure 2-1 provide a historical look at the amount of money DoD spends each year on environmental requirements and breaks down the cost of the five major environmental programs: Cleanup (Clean), Compliance (Comp), Conservation (Cons), Pollution Prevention (P2), and Technology (Tech).

Table 2-1. DoD Environmental Budget (Cost Figures in $Billions) (22)

YEAR	1993	1994	1995	1996	1997	1998	1999	2000	Avg.
BRAC	0.492	0.532	0.637	0.834	0.672	0.833	0.672	0.360	0.629
Clean	1.639	1.965	1.482	1.409	1.311	1.297	1.259	1.264	1.453
Comp	2.127	2.044	2.102	2.260	1.919	2.051	1.889	1.666	2.007
Cons	0.133	0.990	0.154	0.105	0.108	0.103	0.108	0.121	0.228
P2	0.274	0.338	0.287	0.250	0.244	0.278	0.254	0.257	0.273
Tech	0.392	0.410	0.277	0.222	0.223	0.213	0.173	0.199	0.264
TOTAL	5.057	6.279	4.939	5.080	4.477	4.775	4.355	3.867	4.854

The two "end of pipe" costs, Environmental Cleanup and Compliance, account for approximately 70% of the DoD environmental budget. These significant costs explain why DoD has made it policy for weapon system programs to prevent the use of hazardous materials earlier in the acquisition life cycle, where economically and technologically feasible, and avoid the "end of pipe" costs that take money away from other mission critical needs. (22)

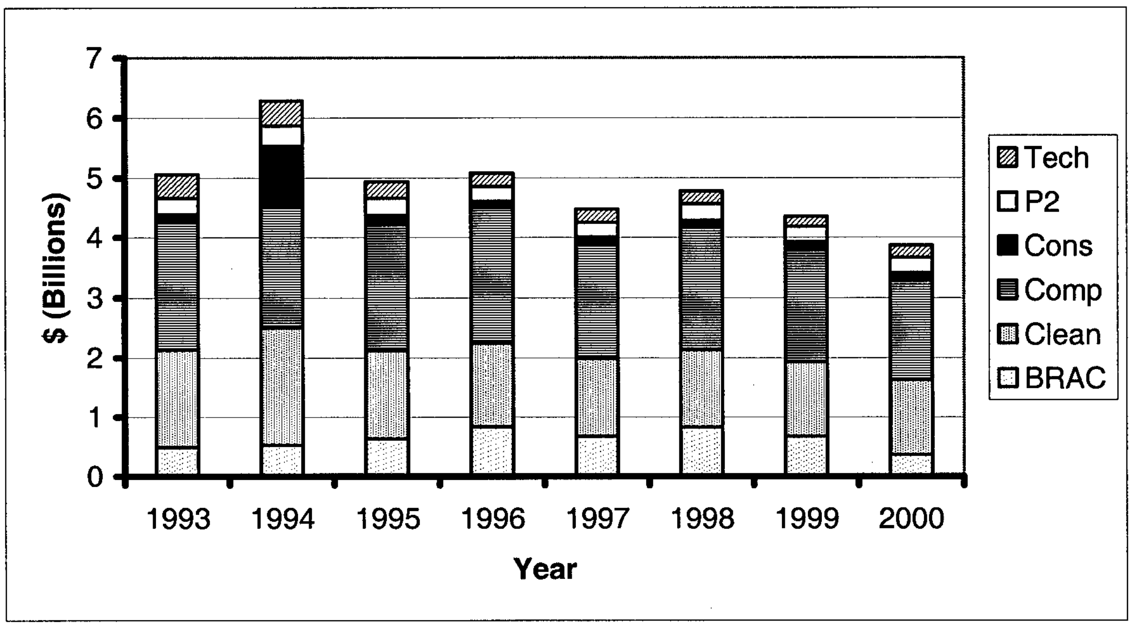

Figure 2-1. DoD Environmental Budget (22)

2.3 Weapon System Acquisition Process

2.3.1 Introduction. This section is specifically written for individuals who do not have a background in DoD acquisition. System Acquisition Management is the process DoD uses to acquire defense systems (i.e., hardware, software, logistics support, and personnel) that support the war-fighters. The primary objectives of this process are

to satisfy the needs of operational users, provide measurable improvements in mission capabilities, and acquire products in a timely manner at a fair and reasonable cost (13, 2.2). Background information is provided on Acquisition Program Management in general, different acquisition categories, life cycles, and work breakdown structures. Finally, a brief overview of the acquisition authorities, policies, and organizations is provided.

2.3.2 Acquisition Program Management. Acquisition Program Management is similar to management in the private sector. DoD managers are expected to plan, staff, organize, control, and lead their organizations in an efficient manner similar to the private sector. However, DoD managers must also perform the following tasks in addition to their typical civilian managerial tasks:

- ensure that public funds are used prudently
- accomplish a mission rather than make a profit
- promote social welfare considerations (e.g. small and disadvantaged businesses)
- ensure all government instructions, policies, guidance, and regulations are followed. (13, 2.1).

2.3.3 DoD Acquisition Categories. There are three major DoD acquisition categories (ACAT) for Air Force weapon system programs: ACAT I, ACAT II, and ACAT III. (Note: there is also category called ACAT IV, but the Air Force does not use this category.) Table 2-2 lists the Research, Development, Testing, and Evaluation (RDT&E) and Procurement Levels and the Major Decision Authority (MDA) that determine the weapon system acquisition categories. Appendix A provides a detailed description of each ACAT. (13, 4.6-4.8)

Table 2-2. Weapon System Acquisition Categories (15, 34)

Category	RDT&E Level (FY 00 dollars)	Procurement Level (FY 00 dollars)	Major Decision Authority (MDA)
ACAT ID	$365M	$2.19B	DAE
ACAT IC	$365M	$2.19B	Service Secretary or CAE
ACAT II	$140M	$660M	Service Secretary or CAE
ACAT III	<$135M	<$640M	Appointed by CAE

2.3.4 DoD Acquisition Life Cycles. The acquisition life cycle is a series of several sequential phases that are separated by decision points called milestones. Currently, DoD is in the process of changing the phases of its acquisition life cycle. Both models will be reviewed and referred as the "Current Acquisition Life Cycle" and the "New Acquisition Life Cycle."

The Current Acquisition Life Cycle will be phased-out in the next couple of years. Figure 2-2 depicts the acquisition life cycle. A description of each phase and milestone is located in Appendix B.

The New Acquisition Life Cycle will be phased-in in the next couple of years. The New Acquisition Life Cycle is developed around a framework of three activities: Pre-systems acquisition, Systems Acquisition, and Sustainment. Figure 2-3 depicts the acquisition life cycle and shows how the framework and phases are incorporated. A description of each phase and milestone is located in Appendix C.

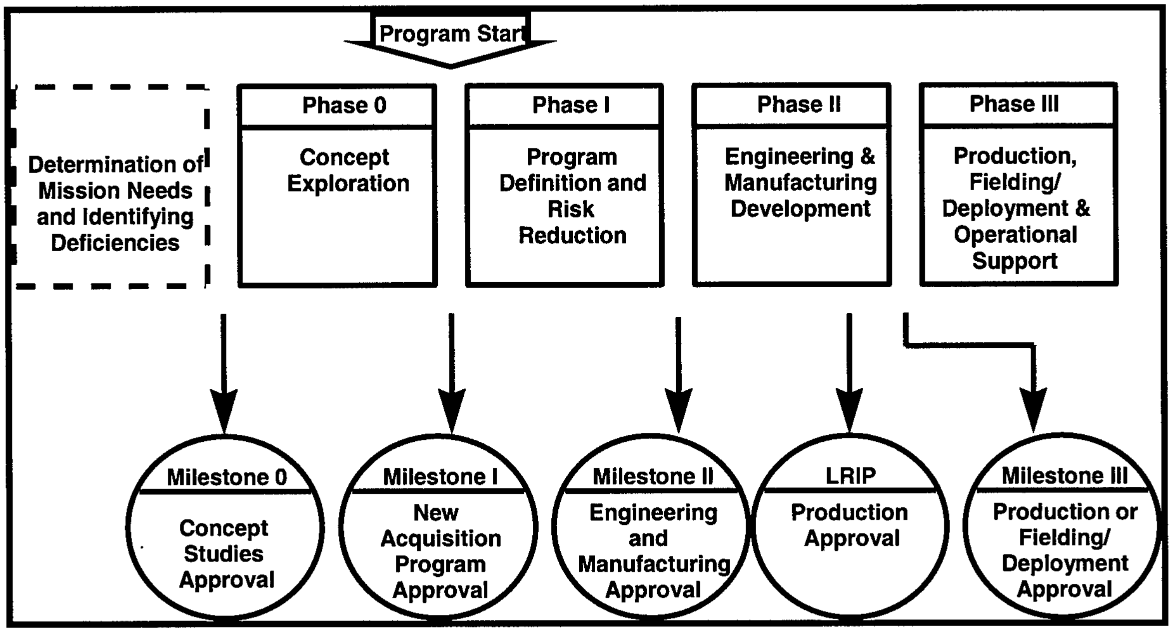

Figure 2-2. Current Acquisition Life Cycle (10, 14)

2.3.5 Work Breakdown Structures. A Work Breakdown Structure (WBS), also called Cost Element Structure (CES), provides a framework for program and technical planning, cost estimating, resource allocations, performance measurements, and status reporting.

WBS elements reflect primary equipment as well as support equipment, management, training, integration, and assembly, spares, and other items, which make up the total system. A WBS is defined in MIL-HDBK-881 as:

> a product-oriented family tree composed of hardware, services, and data which result from a project engineering efforts during the development and production of a defense materiel item and which completely defines the project/program (26).

DoD 5000.2-R states that a WBS is required for all Major Defense Acquisition Programs (MDAP) (24). Appendix D shows an example of a WBS. (4, 10.1)

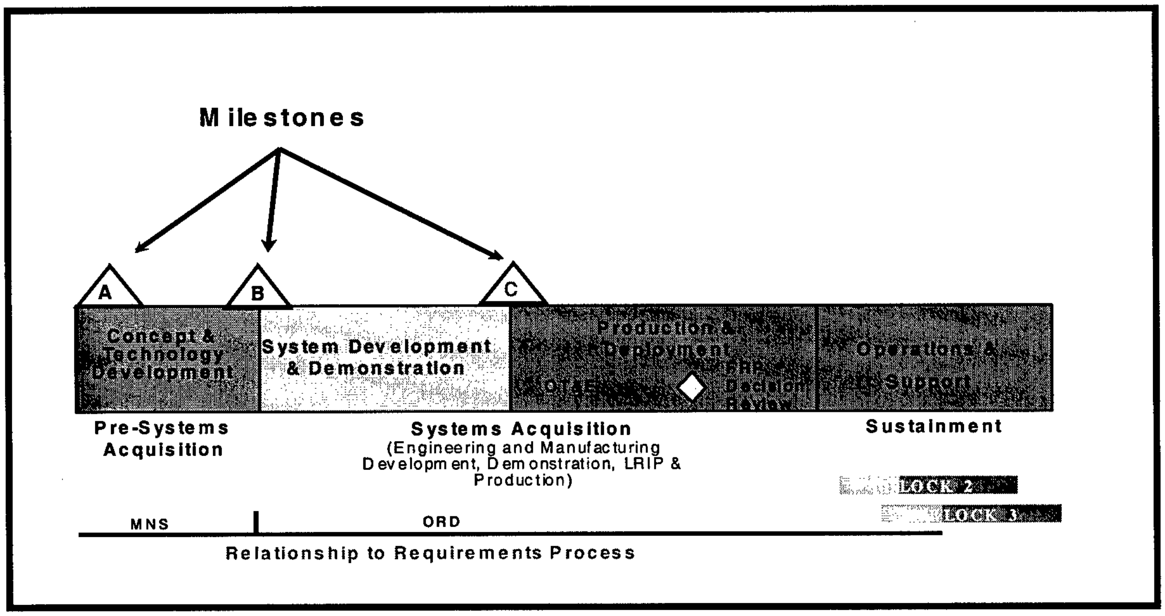

Figure 2-3. New Acquisition Life Cycle (15, 7)

<u>2.3.6 Acquisition Authorities, Policies, and Organizations.</u> It is necessary to understand the "big picture" of DoD acquisition authorities, policies, and organizations to appreciate the difficulties of determining the ELCC of a weapon system. Law and Executive Directives provide DoD the authority to conduct weapon systems acquisition and the associated acquisition policy documents. The Legislative and Executive branches of the government create the environmental laws and policies that face DoD today. Environmental issues are just one category of issues that face these organizations (e.g. politics, funding, contracting, engineering, operations, logistics, etc.). The complexity and diversity of the DoD acquisition organization and process significantly hinders the implementation of new and existing environmental law and policy. Figure 2-4 provides an organization chart showing the complexity of the typical chain of command for a weapon system program. Appendix D provides more detail on the Law, Executive

Directives, and DoD acquisition policy documents associated with weapon system programs. Appendix F describes the specific responsibilities and objectives of each DoD acquisition organization.

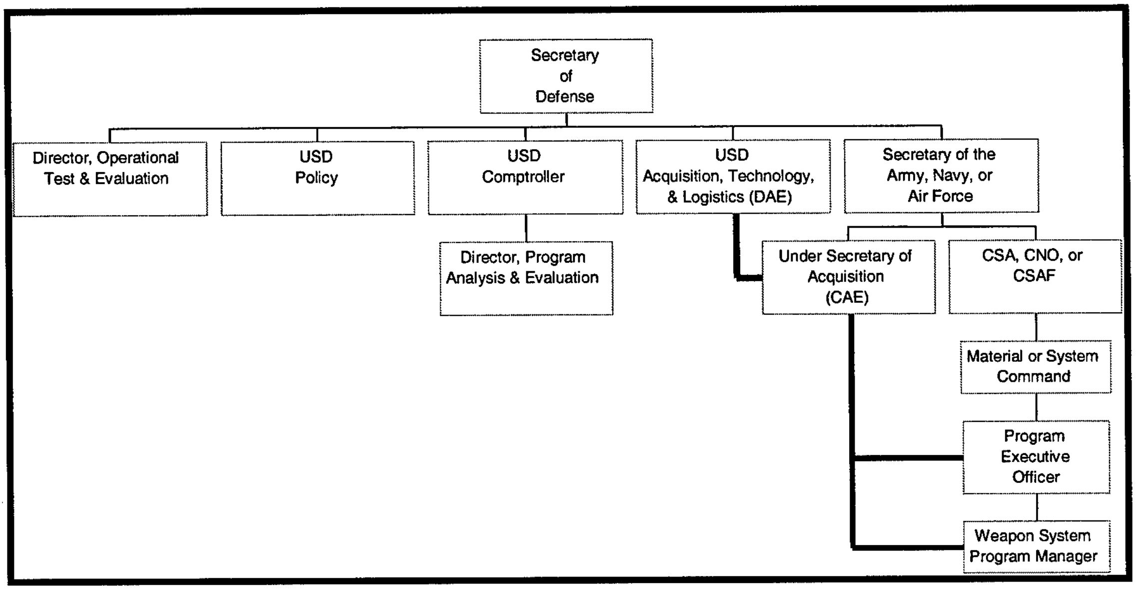

Figure 2-4. DoD Acquisition Organization Chart

2.4 Weapon System Environmental Requirements

<u>2.4.1 Introduction</u>. DoD must comply with numerous environmental laws and policies. This section will summarize the major environmental laws and policies that relate to DoD weapon system programs to show the magnitude and complexity that face managers and professionals. A synopsis of the environmental laws and polices that specifically relate to the ELCC of a weapon system program is provided. Finally, this section will discuss the numerous organizations that are involved in implementing environmental laws and policies.

2.4.2 Major Environmental Laws and Polices. Environmental laws are subdivided into two categories: procedural and substantive. Procedural laws (also know as "future" laws) establish a planning process, impose penalties that may delay programs, and assign compliance responsibility to the weapon system program manager. Substantive laws (also know as "past" and "present" laws) are used to clean up the environment, correct past mistakes, determine who is responsible for paying costs of contaminated sites, and control environmentally hazardous substances and activities. (13, 8.1)

The purpose of the DoD environmental program is to comply with procedural laws and avoid penalties from substantive laws. Environmental management is difficult because of the amount of complex and diverse environmental laws and policies. Appendix G shows the major federal laws, executive orders, DoD regulations and policies that an acquisition manager or professional must consider (Note: there are just as many international, state, and local laws that DoD must also comply with).

2.4.3 ELCC Law and Regulation. Public Law 103-337, Section 815 (Environmental Consequence Analysis of Major Defense Acquisition Programs and Environmental Laws) and DoD 5000-2R, Section 4.3.7 (Mandatory Procedures for Major Defense Acquisition) relate to the ELCC of a DoD weapon system program. Public Law 103-337, Section 815 requires the analysis of the ELCC of a DoD ACAT I weapon system program and specifically states,

> (a) GUIDANCE - Before April 1, 1995, the Secretary of Defense shall issue guidance, to apply uniformly throughout the Department of Defense (on) how to analyze, as early in the process as feasible, the life-cycle environmental costs for such major defense acquisition programs, including the materials to be used, the mode of operations and

maintenance, requirements for demilitarization, and methods of disposal, after consideration of all pollution prevention opportunities and in light of all environmental mitigation measures to which the department expressly commits.

(b) ANALYSIS - Beginning not later than March 31, 1995, the Secretary of Defense shall analyze the environmental costs of a major defense acquisition process as an integral part of the life-cycle cost analysis of the program pursuant to the guidance issued under subsection (a). (46)

DoD 5000.2-R Section 4.3.7 implements Public Law 103-337, Section 815. DoD 5000.2-R makes the following four statements:

1. To minimize the cost and schedule risks that changing regulations represent, the PM shall regularly review environmental regulations and shall analyze the regulations and evaluate their impact on the program's cost, schedule, and performance.

2. The selection, use, and disposal of hazardous materials shall be evaluated and managed so the DoD incurs the lowest cost required to protect human health and the environment over the system's life-cycle, consistent with the program's cost, schedule, and performance goals.

3. The PM shall establish a pollution prevention program to help minimize environmental impacts and the life-cycle costs associated with environmental compliance.

4. In developing work statements, specifications, and other product descriptions, EO 12873 requires (Program Managers) to consider elimination of virgin material requirements, use of recovered materials, reuse of products, life-cycle cost, recyclability, use of environmentally preferable products, waste prevention (including toxicity reduction or elimination), and ultimately, disposal, as appropriate. (24)

Public Law 103-337, Section 815 and DoD 5000-2R, Section 4.3.7 are shown in their entirety in Appendix H and I, respectively.

2.4.4 Organizations Involved in Weapon System Environmental Issues. The number of organizations and professionals (i.e. environmental, safety, health, finance, program management, engineering, etc.) involved with environmental issues in the DoD

acquisition bureaucracy is staggering. However, many of weapon system programs lack the necessary manpower or professionals and depend on other support organizations to provide proper environmental guidance. Figure 2-5 provides an organization chart that depicts the organizations involved with environmental issues in the DoD acquisition bureaucracy. Appendix J describes the basic responsibilities of most of the organizations that participate in just environmental management and supporting activities.

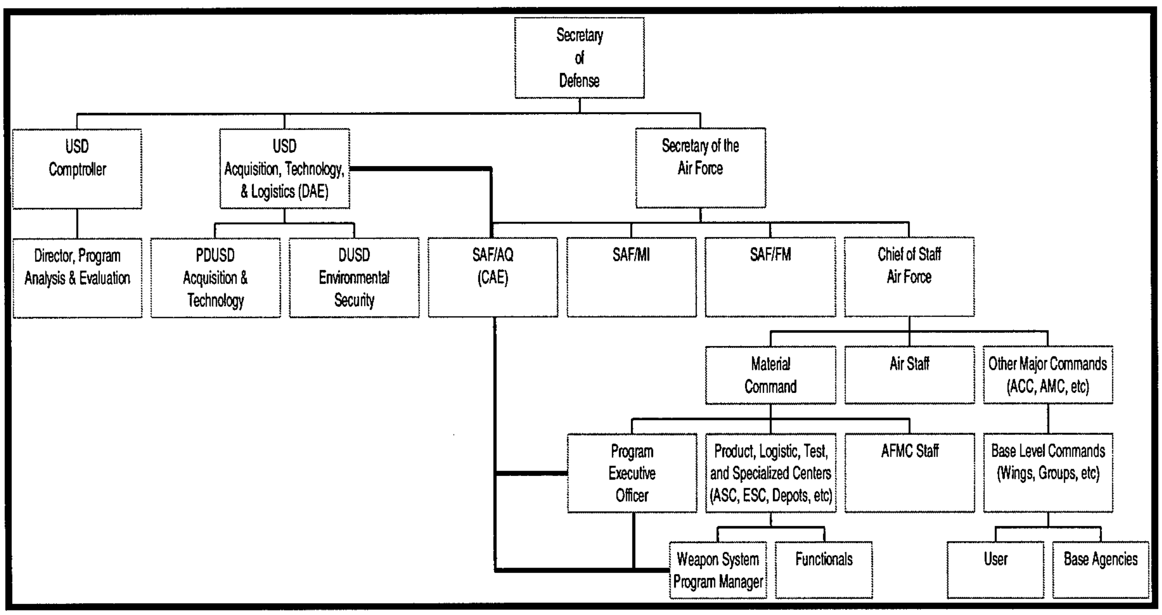

Figure 2-5. DoD Organizations Involved in Environmental Issues

2.5 Weapon System Cost Information

<u>2.5.1 Introduction.</u> To understand how the ELCC for a DoD weapon system program is calculated, cost terms must be clearly defined. Basic cost estimating techniques must also be understood because one of the main reasons for using an ELCC model or methodology is to develop a cost estimate. The first four parts of this section

will provide background information on environmental cost, life-cycle cost, environmental life cycle cost, and specific DoD appropriation categories. The fifth part of this section will provide background information on the different types of cost estimates and their accuracy. The sixth part of this section will describe the different types of cost estimates DoD uses to evaluate a MDAP. The last part of this section will discuss a methodology that is used by DoD to generate cost estimates.

2.5.2 Environmental Cost. Environmental costs can be defined numerous ways. The EPA has a general definition for environmental costs.

> Costs incurred to comply with environmental laws are clearly environmental costs. Costs of environmental remediation, pollution control equipment, and noncompliance penalties are all unquestionably environmental costs. Other costs incurred for environmental protection are likewise clearly environmental costs, even if they are not explicitly required by regulations or go beyond regulatory compliance levels. There are other costs, however, that may fall into a gray zone in terms of being considered environmental costs. (35, 11-12)

The EPA also developed a framework of environmental costs to help with management decision-making. The framework consists of the following four environmental cost categories:

1. Conventional costs - environmental considerations dealing with capital equipment, materials, labor, supplies, utilities, structures, and salvage value.

2. Potentially hidden costs - environmental costs potentially hidden from managers

    a. Regulatory - notification, reporting, monitoring, testing, studies, models, remediation, record keeping, plans, training, inspections, manifesting, labeling, medical surveillance, insurance, protective equipment, pollution control, spill response, taxes, fees, etc.

    b. Up-front - site studies, site preparation, permitting, installation, etc.

c. Voluntary - community relations, outreach, monitoring, testing, audits, training, reports, insurance, planning, feasibility studies, remediation, recycling, etc.

d. Back-end - closure, decommissioning, disposal, site survey, etc.

3. Contingent costs - costs that may or may not be incurred sometime in the future, such as penalties, fines, compliance costs, remediation, property damage, personal injury, legal expenses, etc.

4. Image and relationship costs - corporate image and relationships (customer, insurers, stockholders, regulators, workers, etc.). (35, 7-12)

The American Institute of Chemical Engineers also has a general definition for environmental costs.

> Environmental costs may be defined in different ways, depending on the intended use of the information (e.g., cost allocation, capital budgeting, process/product design, or other management decisions). A cost may not be clearly defined as environmental. Some costs may be classified as partly environmental and partly not. The ultimate goal is to ensure that relevant costs receive appropriate attention. (1, 2-3)

According to the Air Force Environmental, Safety, and Health Cost Analysis Guide (AFESHCAG), environmental cost is a expense that may arise in any or all of the major segments of a program cost estimate that stem from requirements for pollution prevention, compliance, hazardous waste management and disposal, conservation, site cleanup, or final demilitarization and disposal. Environmental costs are subsets of program life cycle costs (e.g. Air Vehicle, Common Support Equipment, Training, System / Project Management, etc.) that have an established relationship with the system-engineering specialty of environmental management. Weapon system environmental costs are not always direct organizational costs; therefore, program managers and cost analysts should ensure that environmental costs are calculated from a total ownership cost perspective. An example of this is the cost impact on the base clinic when a weapon

system program implements a process that requires personnel to undergo medical surveillance. Some other potential environmental costs that might not be direct costs of a weapon system program are personal protection equipment and associated lost productivity, medical treatment and disability costs associated with exposure to hazardous materials, projected equipment loss and personnel injury costs associated with identified system safety and health hazards, special training to protect emergency personnel in cases of system accidents, fires, and potential exposures to pyrolysis products. (7, D.3 and 14-15)

2.5.3 Life-Cycle Cost. The purpose of Life Cycle Cost (LCC) for MDAP is to serve as the cost input for decisions on whether or not to continue, modify, or terminate development, production, and fielding of a system and to provide a basis for budget requests to Congress. (13, 6.2) There are numerous definitions for LCC. Blanchard, an author of several books on LCC, defines LCC as:

> All costs associated with the system or product and applied to the defined life cycle. Life cycle cost includes (but is not necessarily limited to) to the following: research and development, production and construction cost, operation and support, retirement and disposal cost. (2, 9-10)

Seldon, another LCC author, states that "the life cycle cost of an item--its total cost at the end of its lifetime--includes all expenses for research and development, production, modification, transportation, introduction of the item into inventory, new facilities, operation, support, maintenance, disposal, and any other costs of ownership, less any salvage revenue at the end of its lifetime." (41, 9) The importance of LCC is shown in Figure 2-6 by an analogy called the "iceberg effect" by Blanchard. Most people only see the tip of the iceberg; however most of the iceberg is below the surface of the water. The

tip of an iceberg represents acquisition costs and the base of the iceberg is the rest of the "unseen or unrealized" costs (operation, test, support, facility, disposal, etc.).

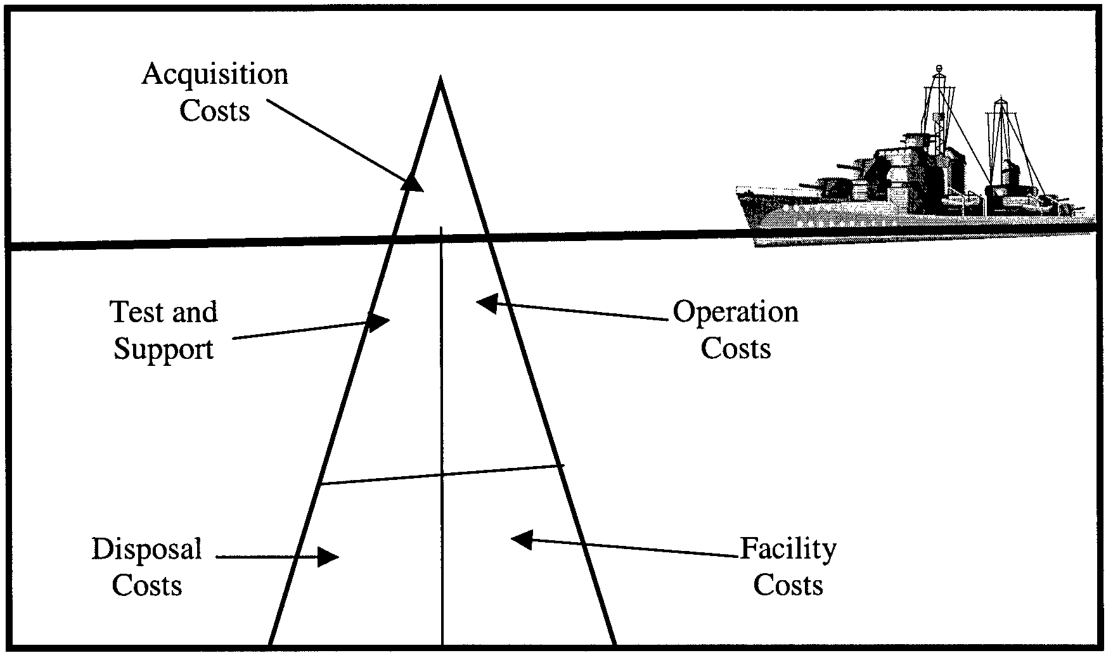

Figure 2-6. Iceberg Effect (2, 6)

There are also numerous government definitions of LCC. The Office of Management and Budget (OMB) defines LCC as "the sum total of the direct, indirect, recurring, nonrecurring, and other related costs incurred, or estimated to be incurred, in the design, development, production, operation, maintenance, and support of a major system over its anticipated useful life span." (37) Executive Order (EO) 12873 defines LCC as "the amortized annual cost of a product, including capital costs, installation costs, operating costs, maintenance costs, and disposal costs discounted over the lifetime of a product." (13, 6-2)

DoD defines cost in a more detailed manner to ensure completeness, consistency, and understanding. According to DoD 5000.4-M, costs are defined as, " ALL WBS elements; ALL affected appropriations; and encompasses the costs, both contractor and in house effort, as well as existing assets to be used, for all cost categories" (14, 3-6).

2.5.4 Environmental Life Cycle Cost. Combining the information from sections 2.5.2 and 2.5.3 provides background to develop a specific definition for the ELCC of a weapon system. This paper will use the following definition for the ELCC of a weapon system: the costs associated with environmental laws, policies, and requirements throughout the entire life cycle of the weapon system. These costs are specifically defined in the EPA framework of environmental costs (conventional, potentially hidden, contingent, and image / relationship costs) as described in section 2.5.2. Appendix K provides an example of potential environmental costs throughout the acquisition process in a WBS format.

2.5.5 DoD Appropriation Categories. DoD has over 100 appropriation categories, but it only uses five appropriation categories to accomplish most of its acquisition objectives. Each appropriation category is defined below:

1. RDT&E - used for expenses necessary for basic and applied scientific research, development, test, and evaluation, including maintenance and operation of facilities and equipment

2. Procurement - used for production and modification of aircraft, missiles, weapons, vehicles, ammunition, shipbuilding and conversion, and other items

3. Operations and Maintenance (O&M) - used for day-to-day expenses such as training exercises, deployments, civilian salaries, and operation and maintaining installations

4. Military Personnel (MILPERS) - used for military pay and allowances, permanent changes of station, and so forth.

5. Military Construction (MILCON) - used for the construction of new facilities.

All five of these appropriation categories contain environmental costs; therefore it is important to understand and track each acquisition category. Table 2-3 provides the obligation period and funding policy for each of the appropriation categories previously listed. (13, 6.10)

Table 2-3. DoD Appropriation Categories (13, 6.10)

Category	Obligation Period	Funding Policy
RDT&E	2 years	Incremental
Procurement	3 years	Full
O&M	1 year	Annual
MILPERS	1 year	Annual
MILCON	5 years	Full

Figure 2-7 shows where each DoD Appropriation Category is spent throughout the acquisition life cycle. The different proponents throughout the acquisition life cycle are the Program Executive Officer (PEO), Program Manager (PM), and the Non-PEO/MAJCOM individuals. The PEO and PM are the acquisition leaders responsible for developing weapon systems. The Non-PEO/MAJCOM proponents are the operation, logistic, medical, and support leaders who use the systems developed by the PEO and PM. The PEO and PM are evaluated on the ability of the program to stay within schedule and budget and to meet the operational requirements. Because of the acquisition process of milestones and budget / funding process, short-term cost strategies are of significant concern to the PEO and PM. The PEO and PM try to minimize long-term costs when possible, but they are limited by the amount of acquisition funds (R&D and procurement)

that are available to reduce the total LCC. Therefore, the Non-PEO/MAJCOM proponent might face higher operation and support costs because of economic decisions made early in the acquisition process. Note: Figure 2-7 does not show any proponents for the Concept Exploration Phase; however, both the PEO/PM and Non-PEO/MAJCOM are proponents during this phase.

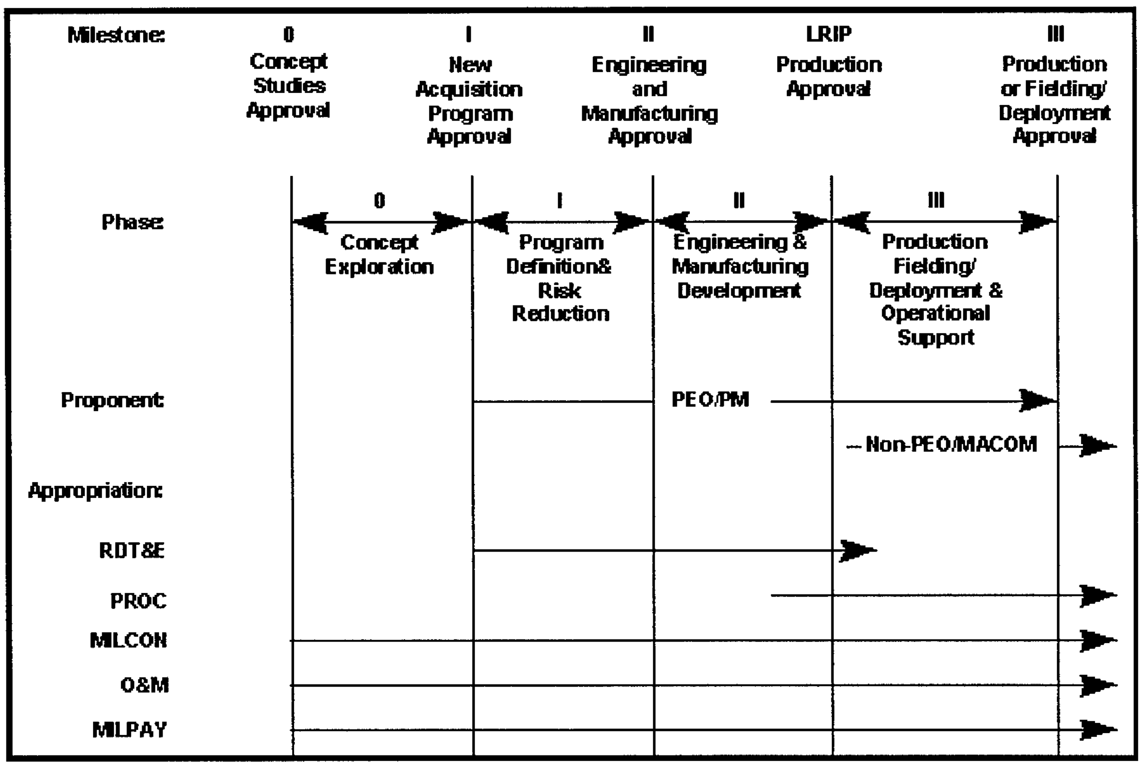

Figure 2-7. Acquisition Life Cycle Appropriation Categories (10, 46)

<u>2.5.6 Types of Cost Estimates</u>. ELCC models and methodologies are tools to help develop an ELCC cost estimate; therefore, it is important to understand the different types of cost estimates. There are four major types of cost estimates: analogy, parametric, engineering, and actual costs. Analogy estimates are used to subjectively compare a new system with one or more existing similar systems for which accurate costs

and technical data already exist. This estimate is quick, inexpensive, and easy to change. Its weaknesses are that it is subjective and not precise. Parametric estimates allow analysts the ability to generate and estimate based on system performance or design characteristics. This estimate uses a database of elements from similar systems and makes statistical inferences about the cost estimating relationships. Its weaknesses are that it is moderately subjective and is only as precise as the existing database. Engineering estimates are used to cost every WBS element in the entire system. This estimate is a very accurate method and reasonably objective. Its weaknesses are that it is very expensive, time consuming, and difficult to manipulate. Actual estimates are used to extrapolate from actual costs that were contracted for or actually incurred on that system during an earlier period. This estimate is very accurate and reasonably objective. Its weakness that these figures are usually not available until after the estimate is complete. (13, 7.2)

2.5.7 DoD Cost Estimates. ELCC must be integrated into weapon system program cost estimates to be properly accounted for. DoD uses three types of cost estimates for weapon system program milestone reviews: Program Office Estimates (POE), Component Cost Analysis (CCA), and Independent Cost Estimates (ICE). A POE is a LCC estimate completed by a program office that covers costs from program initiation through disposal. A CCA is a separate cost estimate prepared by one of the cost analysis agencies that reviews the POE computations, methodologies, and assumptions. An ICE is a separate and distinct cost estimate prepared by the Cost Analysis Improvement Group (CAIG) – an organization outside of the Service acquisition community chain. (13, 7.4)

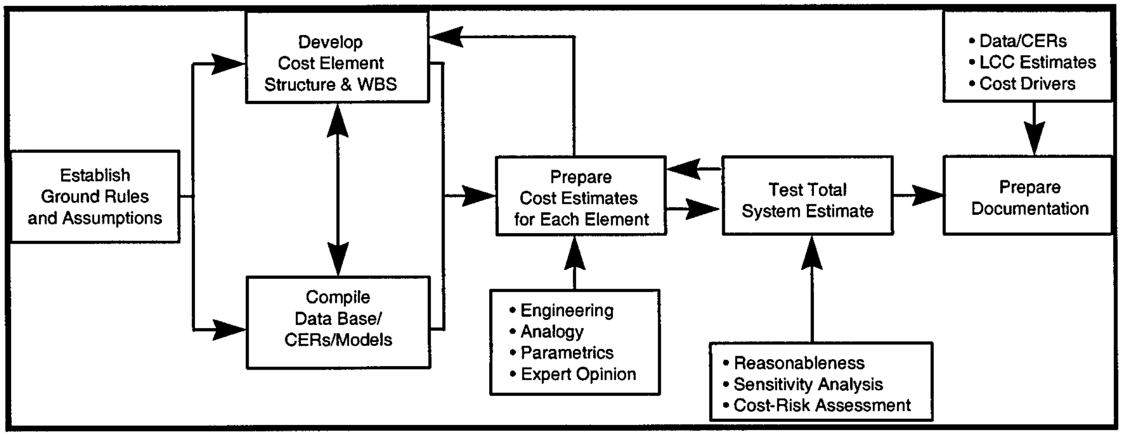

Figure 2-8. Cost Estimating Methodology (10, 30)

<u>2.6.2 ELCC Methodology versus ELCC Model</u>. ELCC methodology and ELCC model are often used together and thought of as synonymous. However, ELCC methodologies are different from ELCC models. For the purposes of this paper, methodology is a system of principles, practices, and procedures applied to a specific branch of knowledge (36, 791). The main purpose of using a methodology is to provide an organization a standardized and systematic way of analyzing a real world phenomenon. An ELCC methodology organizes and presents environmental cost data that assist an analyst with conducting proper analysis and making rational decisions. A model is a set of relationships and logical assumptions that represent a real world phenomenon. There are four main purposes for using a model: simplicity, cost, insight and understanding, and time. The main reason for using a model is to simplify a problem it represents to reduce the amount of analysis needed to make a rational decision. Using a model to simulate a real world phenomenon is usually cheaper than the performance and evaluation of an activity. A model can also provide insight and understanding of a

complex problem to help a manager make a decision. Finally, using a model can help reduce the amount of time required to evaluate a real world phenomenon and make a decision. (38, 1-4) Both ELCC methodologies and models are an integral part of calculating the ELCC of a weapon system, but it is important to note the differences between the two definitions.

Table 2-4. Cost Estimating Documentation Checklist (6, 19)

Introduction	
1.	Table of Contents
2.	Program Title and Program Elements (PES)
3.	Reference to current PMD, if applicable, and the CARD
4.	Purpose and Scope of Estimate
5.	Cost Estimating Team Members (organization, phone number, and area estimated)
6.	Description of System or Effort being estimated (phases, which costs are included, etc.)
7.	Program schedules
8.	Applicable Contract Information
9.	Cost Estimate Summary by FY in Air Force Form 1537 format in BY and TY dollars
10.	Ground Rules and Assumptions used to build the estimate
Detailed Estimate	
1.	Estimate details presented by appropriation (e.g., RDT&E, production, etc.)
2.	Each section of the estimate listed by WBS, cost element structure (CES), or other cost element.
3.	Detailed methods, sources, and calculations by WBS, CES, or other cost element. Include a FY phasing and rationale for the phasing method.
4.	Sufficient detail to allow an independent analyst to duplicate the estimate if given access to the same data.
5.	Rationale for selecting a specific cost estimating method by WBS, CES, or other cost element.
6.	When referencing analogous systems, identify the data source used (e.g., Selected Acquisition Reports, Defense Acquisition Executive Summary, CPRs, etc.)
7.	Include crosschecks, reasonableness, and consistency checks addressed by WBS, CES, or other cost element. Specific references to a study, analogous system, and/or other documented references are required.
8.	Provide a cost track to the prior estimate and rationale for any differences.
9.	A reconciliation between the CCA and POE.

2.6.3 Existing ELCC Methodologies and Models. There are several different types of ELCC methodologies and models in use today. This section will briefly summarize the EPA's role in the development of ELCC methodologies and models.

Then it will delve into three ELCC methodologies that different DoD organizations have developed.

2.6.3.1 EPA ELCC Methodologies and Models. Over the past 10 years, the EPA Office of Pollution Prevention and Toxics has spearheaded the development of environmental life cycle costing (also know as Total Cost Assessment (TCA) or Environmental Accounting (EA)). In 1992, the EPA created an organization called the Environmental Accounting Project which was comprised of the following stakeholders: the Institute of Management Accountants, American Institute for Certified Public Accountants, Chamber of Commerce, Business Roundtable, and American Association of Cost Engineers. The mission of this organization is "to encourage and motivate business to understand the full spectrum of their environmental costs, and integrate theses costs into decision making" (32). This organization has provided numerous publications, case studies, and models have been made available for different government and private organizations to evaluate environmental life cycle costs. Summaries of the applicable EPA case studies are provided in Chapter 4 to validate the importance of using an ELCC methodology or model. (32)

In September 1995, the EPA Environmental Accounting Project completed an effort that provided managers in government and private organizations a compiled list of all available decision-making tools and software that incorporate environmental information. In its report "Incorporating Environmental Costs and Considerations into Decision-Making: Review of Available Tools and Software," the EPA discusses the importance of ELCC and provides basic information on several different models and methodologies. The study also points out that most organizations do not use these

methodologies to evaluate environmental considerations because they are more comfortable with traditional cost accounting methods and effective environmental decision making tools are not completely accepted. The EPA developed a 6-step methodology to help these companies establish environmental accounting procedures:

1. Identify problem and assess needs
2. Develop methods for estimating and including environmental costs
3. Test for practicability and utility
4. Establish a new standard integrated methodology or methodologies
5. Test for practicability and utility
6. Incorporate the methodology or methodologies into existing decision-making and accounting systems (34, 3-23)

Even with this new methodology, companies still have not reached a consensus on environmental life cycle costing because research is still needed in environmental estimating procedures, finding hidden or contingent environmental costs, and developing environmental cost databases. (34, 3.23-3.24)

This EPA reference is an excellent source of information; however, most of the models described in the report are not robust enough to evaluate the entire environmental life cycle cost of a major weapon system. These models only tend to track some environmental costs (i.e., effects of hazardous materials and waste) or evaluate only a portion of the weapon system life cycle (usually the Operation and Support phase). These models are not appropriate because they do not account for the complexity of a weapon system program and do not have suitable environmental cost data.

2.6.3.2 DoD ELCC Methodologies and Models. DoD has adopted or developed numerous ELCC methodologies and models over the past 10 years. Most of these ELCC methodologies and models are summarized in two documents. The first document, "Evaluation of Environmental Management Cost Estimating Capabilities for Major Defense Acquisition Programs," is a DoD Report written by the Capstone Corporation for the Office of the Director of Program Analysis and Evaluation. This DoD report developed a hierarchical WBS for environmental management activities and analyzed 30 different environmental cost estimating and analysis tools (21, 1). The second document, "Environmental, Safety, and Health Cost Analysis Guide," is an Air Force publication written by EER Systems, Inc., for Air Force Material Command (AFMC). This Air Force publication presented basic environmental management cost estimating information and analyzed ten different environmental cost estimating tools (7, 1). The problem with most of the ELCC methodologies and models discussed in both documents is that they have been discarded or are not used because they are either too complex or do not meet the specific needs of the user. An example of this problem is the Environmental Cost of Hazardous Operations (ECHO) Model, a complex ESH cost model that correlates weapon system materials to hazardous substance quantities to determine environmental cost drivers. Weapon system programs avoid using the ECHO Model because of the amount of data required and analysis needed for their ELCC. Chapter 4 provides summaries of both documents to validate the importance of using an ELCC methodology or model.

In the past few of years, three different organizations within DoD have developed two methodologies and one model that can be used to calculate ELCC. The

methodologies and model do not specifically address Air Force weapon system programs, but they are appropriate and can be adapted. The next three sections will briefly introduce these ELCC methodologies and model. Note: Chapter 4 will analyze and evaluate these methodologies and model in more depth.

2.6.3.2.1 Army ELCC Methodology. The U.S. Army Environmental Center (USAEC) contracted Platinum International, Inc. (PII), to document the ELCC of the Apache and Comanche helicopters (Note: these applications will be analyzed in more detail in Section 4.2.3.3.4). USAEC and PII developed an ELCC methodology that was consistent with the U.S. Army Cost and Economic Analysis Center (USACEAC) Cost Analysis Manual's procedures for Independent Cost Estimates. The USACEAC Cost Analysis Manual uses a WBS that breaks environmental costs into eight different categories:

1. Compliance, Plans, Permits, Reports, Tests and Assessments
2. Pollution Prevention / Waste Management
3. Natural / Cultural Resource Preservation
4. Remediation and Restoration
5. Demilitarization and Disposal
6. Management
7. Costs and Liability Risk
8. Contractor Environmental Costs.

These categories are applied across each phase of the acquisition life cycle and the cost estimate is broken down into each DoD Appropriation Category. (11, 2.3-2.5) (12, 2.3-2.5)

To develop a specific ELCC, environmental cost data must be gathered. For each weapon system program, PII collected the environmental cost data from associated unit and depot installations by using a five-step approach. The first step is developing an inventory of all environmental activities at every unit or depot installation (e.g., routine maintenance, engine replacement, hazardous material or waste storage and disposal, etc.). The second step is assessing significant environmental impacts from each of the environmental activities (e.g., permits, trade studies, compliance costs, etc.). The third step is determining the appropriate cost of each environmental activity. If actual costs were not available, analogies from similar weapon system programs were used. If costs were buried in contracts or POE figures, additional analysis was used to determine specific environmental costs. The fourth step has three parts: interpreting the results, documenting them in the appropriate WBS category, and inputting the information into an EXCEL spreadsheet. (Note: this methodology will eventually be adapted to Automated Cost Estimating Integrated Tools (ACEIT), a cost-modeling program.) The final step is validating the ELCC with reviews from the Weapon System Program Manager, USACEAC, USAEC, and USACEAC Environmental Cost IPT. The Weapon System Program Manager ensures the data was collected and interpreted correctly. USACEAC analyzes the cost figures and ensures the ELCC is calculated properly. Environmental experts from USAEC review the specific environmental media assumptions and calculations. The USACEAC Environmental Cost IPT completes the validation by conducting a final review. (11, 2.6) (12, 2.6)

Table 2-5 is an example WBS spreadsheet used in Step 4 to document and calculate the ELCC of a weapon system. The spreadsheet contains the CES Number,

WBS / CES description, Sunk Fiscal Year 1999 dollars (FY 99$), Future FY 99$, and Total FY 00$. The CES Number and WBS / CES Description are used to categorize each environmental cost. Each WBS / CES Description has a separate Cost Documentation Format Sheet (not shown) that details the specific cost definition, assumptions, cost inclusions or exclusions, data sources and adjustments, methodologies and calculations, limitations, and results. The Sunk FY 99$ column is the amount that has already been spent on the corresponding WBS Item. The Future FY 99$ column is the amount predicted to be spent on the corresponding WBS Item. The Total FY 00$ is the sum of the Sunk FY 99$ and Future FY 99$ figures.

Table 2-6 is an example summary spreadsheet also used in Step 4 to summarize environmental costs. This spreadsheet uses the cost figures from Table 2-5 and organizes them by appropriation category. The purpose of this spreadsheet is to provide the user with a simplified document that can be used in presentations or reports.

The Army ELCC Methodology is an environmental accounting system. It can organize and account for all environmental costs so the user can perform analysis, render decisions, or develop presentations. The major limitation of the Army ELCC Methodology is the availability of the necessary environmental cost data. The level of accuracy of the Army ELCC Methodology is completely dependent on the accuracy of the environmental cost data. It is difficult and sometimes expensive to find, gather, organize, and maintain all the necessary environmental cost data for the entire weapon system for this estimate.

Table 2.5. Example Army ELCC Methodology WBS Spreadsheet (11, 3.1)

CES Number	WBS/CES Description	SUNK FY 99$	FUTURE FY 99$	TOTAL FY 00$
7.0	**Environmental Life-Cycle Cost**			**329,773,820**
7.1	**Compliance, Plans, Permits, Reports, Tests & Assessments**			6,199,986
7.11	*RDT&E*			1,708,577
7.111-1	NEPA (ESH)	1,050,000	350,000	1,432,340
7.111-2	Site Surveys		270,000	276,237
7.12	*Procurement*			2,394,054
7.121-1	NEPA (ESH)		1,680,000	1,718,808
7.121-2	Site Surveys		660,000	675,246

Table 2-6. Example Army ELCC Methodology Summary Spreadsheet (11, 3.5)

Summary:	
Total Environmental Costs	329,773,820
Cost by Appropriation:	
Research, Development, Testing and Evaluation (RTD&E)	27,886,007
Procurement	126,729,828
Military Construction, Army (MCA)	0
Military Personnel, Army (MPA)	0
Operation and Maintenance, Army (OMA)	175,157,985

2.6.3.2.2 Navy ELCC Model. The Naval Air Warfare Center Aircraft Division (NAWCAD) in Lakehurst, New Jersey, is currently developing an ELCC model that uses a simplified version of the Environmental Cost of Hazardous Operations (ECHO) software developed by Telecote, Inc. ECHO is a complicated ELCC model that users found cumbersome and time consuming to use. Environmental acquisition professionals can use the Navy ELCC Model to develop a quick estimate of the following

environmental costs for several different weapon systems (FA18, F14, AV8, E2/C2, S3, P3, EA6, H46, and H53):

1. Air emissions planning and reporting
2. Air emissions control
3. Hazardous material management
4. Hazardous material purchase
5. Hazardous material disposal
6. Industrial wastewater treatment. (27, 1)

This model uses a database of environmental costs developed by NAWCAD. The database develops several Quantity Estimating Relationships (QER) and Cost Estimating Relationships (CER) based on historical aircraft programs. A QER uses different characteristics (i.e., surface area or weight) to predict the amount of hazardous material, hazardous waste, and industrial wastewater treatment generated by an aircraft. A CER is used to predict environmental costs of an aircraft base on one or more QER. The data was collected from the for major processes of the acquisition life cycle:

1. Production. The production environmental cost data was gathered from FA18 production at the Northrup Grumman facility in El Segundo, California. These costs are difficult to estimate because many aircraft manufacturers produce more than one aircraft at their facilities and each facility usually produces only certain parts of these aircraft. The El Segundo facility was chosen because it primarily produces 65% of the FA18. This data was then extrapolated to an entire aircraft.
2. Organizational and Intermediate (O & I) level maintenance. The O & I environmental cost data was collected from the Environmental Systems

Allocation (ESA) database developed by the Naval Facilities Engineering Service Center (NFESC). This environmental cost data includes costs associated with hazardous materials and waste for four different locations and eight different aircraft.

3. Depot level maintenance. Depot level data was collected from Naval Aviation Depots (NAVDEP) at North Island and Cherry Point. Hazardous material, hazardous waste, and industrial wastewater data was collected from each shop and then allocated to nine specific aircraft based on associated maintenance hour percentages.
4. Demilitarization and disposal. This environmental cost data was collected from the Aerospace Maintenance and Regeneration Center (AMARC). This costs data includes costs associated with hazardous material and waste costs based on dividing the number of aircraft AMARC manages per year. (27, 1-3)

This methodology uses Microsoft Access. Figure 2-9 shows the input screen where a user would select several data elements (e.g., number of aircraft, location, etc.) that enable the program to calculate the specific ELCC. Figure 2-10 shows the calculation screen that displays the four major processes (production, O&I level maintenance, depot level maintenance, and disposal) and displays the associated costs. Figure 2-11 shows the data screen where the user can view, manipulate, or insert environmental cost data.

The main advantage of the Navy ELCC Model is that it calculates a quick ELCC estimate that provides a user with documented cost data that can be used for further analysis. The limitations of this model are that it only accounts for part of the acquisition life cycle and the lack of availability of the necessary environmental cost data. Analyses using this methodology are only as good as the environmental cost data available in the database. This model also does not include the following environmental costs: Research and Development, Pollution Prevention, National Environmental Policy Act (NEPA) Studies, cleanup of aircraft accidents, and Program Environmental Safety and Health Evaluations (PESHE).

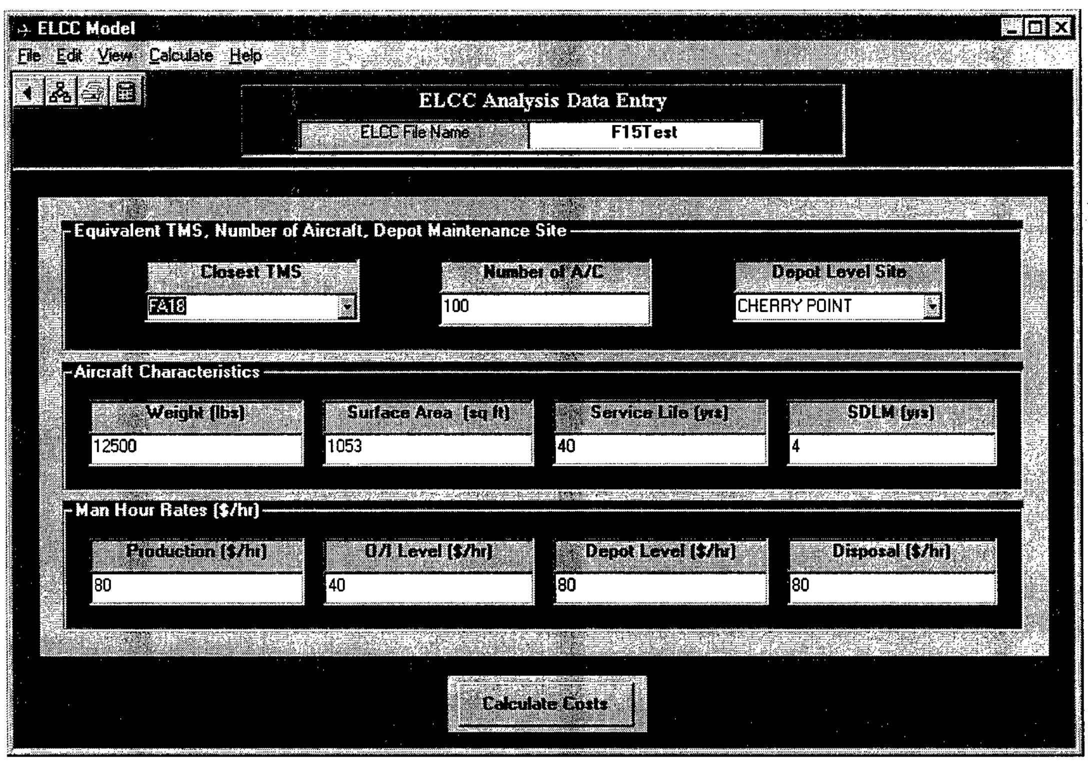

Figure 2-9. Navy ELCC Model Input Screen (27)

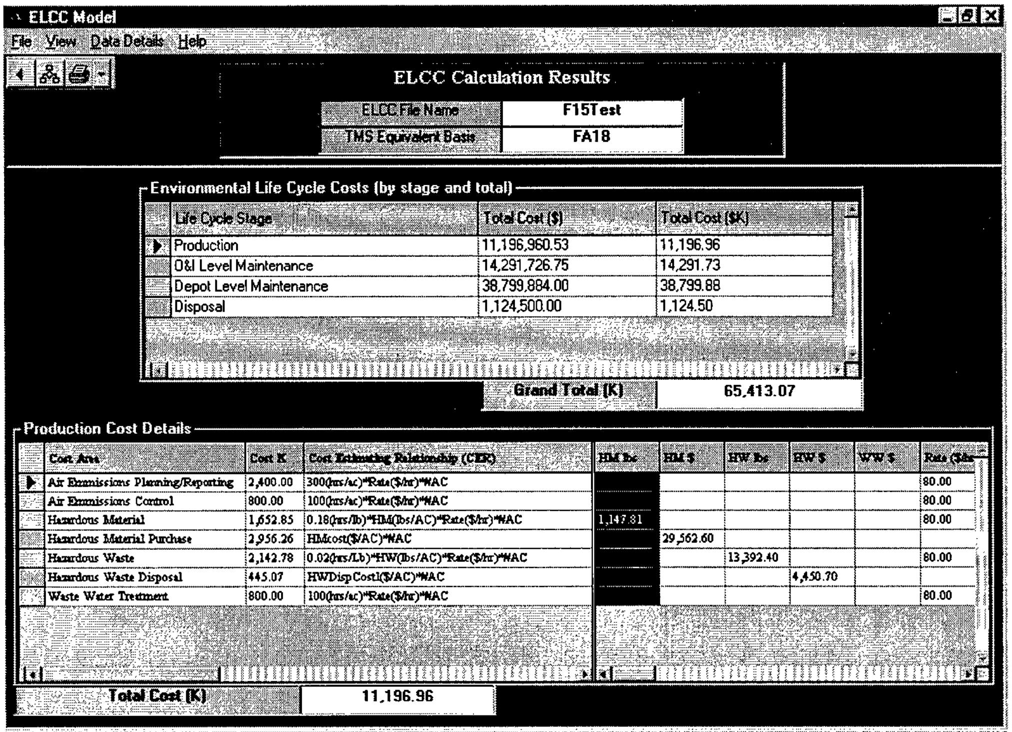

Figure 2-10. Navy ELCC Model Calculation Screen (27)

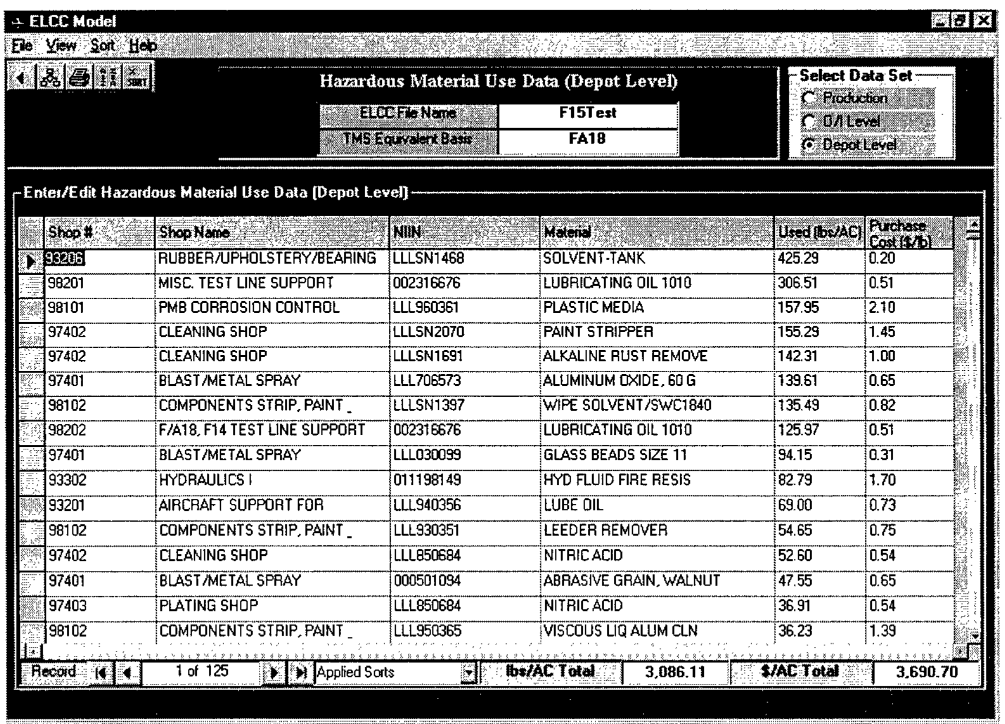

Figure 2-11. Navy ELCC Model Data Screen (27)

2.6.3.2.3 Environmental Cost Analysis Methodology. The National Defense Center of Environmental Excellence contracted Concurrent Technologies Corporation (CTC) to develop the Environmental Cost Analysis Methodology (ECAM). This methodology is used by the Environmental Security Technology Certification Program (ESTCP), a demonstration and validation program for innovative technologies that target urgent environmental needs by DoD. ECAM was developed to provide a consistent means of evaluating environmental costs and technologies that address compliance and pollution prevention issues. ECAM was specifically designed to evaluate individual process technologies fielded in the operation and support phase and not as a life cycle costing tool to evaluate new systems over the entire life cycle of a weapon system. A weapon system has numerous processes, technologies, and other idiosyncrasies that are too complex for ECAM to analyze together. ECAM employs terminology developed by the EPA's report "An Introduction to Environmental Accounting as a Business Management Tool: Key Concepts and Terms." ECAM uses an EXCEL-based software tool called P2/FINANCE developed by the Tellus Institute to facilitate the financial analysis portion of the methodology. (16, 1:68)

ECAM uses a four-level (or step) process to develop an ELCC of an individual process technology. Level 1 identifies the process and direct environmental costs. This level requires the user to define the process, establish process boundaries, develop process flow diagrams, quantify resources used in the process, and identify unit costs with the resource quantities used in the process. Level 2 identifies indirect environmental costs. The user must identify the environmental activities supporting the process, identify resources consumed by environmental activities, and assign environmental costs to the

process. Level 3 identifies other process improvement costs and is considered optional unless there is a potential to identify significant costs and process improvement benefits that may affect the final decision. This level evaluates other non-environmental support and overhead costs and impacts associated with productivity. ECAM provides data collection forms, blank process flow diagrams, blank input/output diagrams, an environmental activities checklist, and a checklist of qualitative environmental factors for Levels 1, 2, and 3 that help the user develop a more accurate and standardized ELCC cost data. Level 4 is the financial data analysis portion of the process. Here the user inputs the data into P2/Finance to organize and analyze cost data, calculate annual cash flows, and generate financial indicators (payback, net present value, and internal rate of return) for investments. Figure 2-12 illustrates the ECAM approach. (16, 1:35)

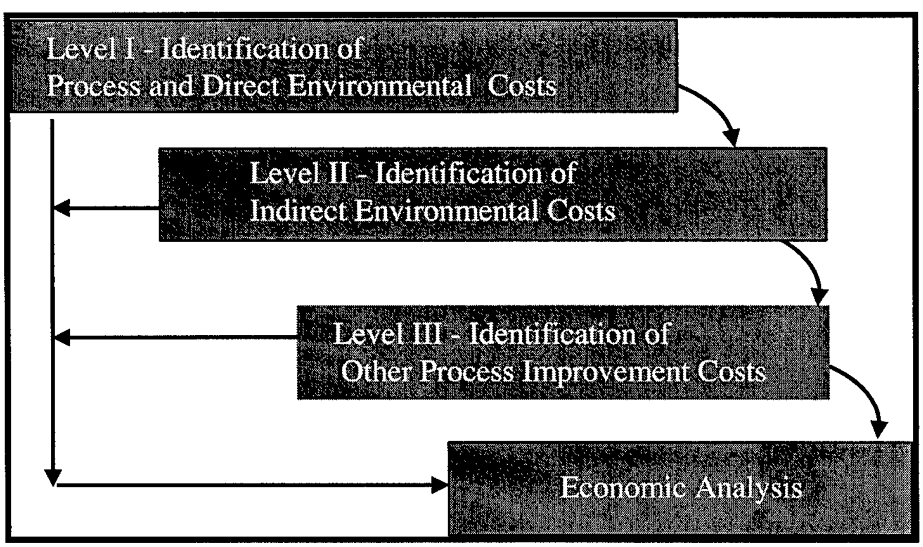

Figure 2-12. ECAM Approach (43)

ECAM was validated at Lake City Army Ammunition Plant in Independence, Missouri, by evaluating an ammunition manufacturing process that was modified to reduce the use of hazardous materials. ECAM has also been applied at five other DoD installations that fielded or evaluated different technologies that where designed to eliminate or reduce potentially adverse environmental impacts and reduce costs. These installations and technologies will be analyzed in more detail in Section 4.2.3.3.4. (17, iii)

The strong point of ECAM is that it is a standardized capital investment decision tool used for economic analyses of new environmental technologies. It provides a methodology that allows for comparison and prioritization of projects, ensures greater accuracy and higher confidence by using checklists and flow diagrams, and uses economic indicators that accounts for the time value of money. Just like the Army ELCC Methodology and Navy ELCC Model, ECAM is only as good as the user and the environmental cost data inputted into the program. Therefore, the user must use this methodology carefully and understand the intricacies of the environmental cost data.

2.6.4 Purposes and Uses of ELCC Methodologies and Models. ELCC methodologies or models are usually used in two different ways. First, an ELCC methodology or model can determine the total ELCC of a product or process by calculating all environmental costs occurred of the entire life cycle. This allows an organization to know what environmental costs they must budget for and help determine a strategy to reduce the overall burden. A mature weapon system program would use an ELCC methodology or model to find significant cost drivers in operation, support, and disposal environmental costs. A young weapon system program would use an ELCC

methodology or model to find significant cost drivers in the production process and try to minimize operation, support, and disposal environmental costs. An example of how an ELCC methodology or model is used this way is the Army ELCC Methodology discussed in Section 2.6.3.2.1. The Army ELCC Methodology was successfully applied to the Apache, a mature weapon system program, and the Comanche, a young one. Second, an ELCC methodology or model can evaluate different alternatives by calculating and comparing their respective ELCC for a particular weapon system. This allows an organization to objectively analyze the environmental costs of different alternatives and conduct what-if scenarios to provide additional information for a decision-maker. An example of this type of ELCC methodology or model is the Navy ELCC Model and ECAM as discussed in Sections 2.6.3.2.2 and 2.6.3.2.3, respectively.

2.6.5 ELCC Methodology and Model Assessment. There are numerous ways to assess and evaluate different methodologies and models. The Air Force has a long history of using LCC methodologies and models, and many individuals or organizations have developed criteria for evaluating these models or methodologies. The EPA has also developed criteria for evaluating environmental methodologies or models. This section will discuss four different sets of model assessment criteria developed by the Air Force or EPA. These criteria are appropriate for use evaluating ELCC methodologies and models. In Chapter 3, these four sets of criteria will be compared and combined into one set of criteria applicable to weapon system ELCC methodologies and models.

2.6.5.1 Joint AFSC / AFLC Commanders' Working Group on LCC. The Joint Air Force Systems Command (AFSC) and Air Force Logistics Command (AFLC) are the predecessors of today's Air Force Material Command (AFMC). These

organizations developed a Joint AFSC / AFLC Commanders' Working Group to improve the working relationships and effectiveness between these two organizations. One of the major pieces of work this group completed was a set of desirable model characteristics that could be used to evaluate the effectiveness of a particular model. The AFSC / AFLC developed the following set of desirable LCC model characteristics:

1. Completeness – include all elements of cost appropriation to the decision issue under consideration.

2. Sensitivity – must be sensitive to the specific design of program parameters being studied, so that cost differences between alternatives can be determined.

3. Availability of data – must be feasible to obtain accurate input data.

4. Documentation – provide accurate model descriptions so that work can quickly be reviewed and understood by others. (45, 35-36)

2.6.5.2 Seldon LCC Features. M. Robert Seldon, an LCC expert and author, noted that there are many desired features of a model, but some can be contradictory, e.g., simplicity and comprehensiveness. Finding appropriate characteristics should be considered in designing the model. Seldon developed the following 15 suggestions as the desired features of a LCC model:

1. Economy – must be cheap to develop, to alter, to provide data with, and to operate.

2. Speed – must be easy to set up, operate, and change.

3. Ease of operation – should be standardized, useable by different types of personnel (i.e. designers, other technical personnel, LCC specialists, etc.), and easy to input data at different levels of the WBS.

4. Program and design sensitivity – clearly show the cost impact of design and program characteristics.

5. Feasible data requirements – should only require available data.

6. Economic capability and flexibility – provide a discounting method and inflation rate that can be selected by the user.

7. Ease of transition to detailed quotation – output should easily fit quotation format.

8. Usefulness throughout a program – should be useful through all phases of the acquisition life cycle.

9. Tolerance and helpfulness – should be tolerant of input errors and provide user with correct deviant values.

10. Performance of sensitivity analyses – should be able to vary one or more parameters over a range of values.

11. Modular format – easy to repair and modify.

12. Security – should be secure from unauthorized access.

13. Inclusiveness – should include all significant costs and influences on costs.

14. Authoritativeness – should be accepted by management and the customer as authoritative. (41, 165-169)

2.6.5.3 ASC/FM LCC Requirements. The Aeronautical Systems Center Financial Management (ASC/ FM) Office in AFMC uses many different LCC models in support of acquisition programs Air Force-wide. This organization developed the following list of seven primary requirements that a LCC model should meet to be of value:

1. Completeness - must include all elements of life cycle cost appropriate to the decision issue under consideration.

2. Sensitivity - must be sensitive to the specific design or program parameters under study to resolve life cycle cost differences among the alternatives.

3. Validity - should represent the real-world environment in question.

4. Availability of Input Data - accurate input data must be available for a life cycle cost model to be useful.

5. Documentation - results should be well documented so the work can be quickly reviewed and easily understood by others.

6. Analysis Results - end product of a design trade study should be analysis results that can serve as a valid and logical basis for selecting a preferred design.

7. Consideration of Other Design Objectives - many design objectives are important in addition to minimum life cycle cost and these costs should be documented and justified properly. (6, B-1)

2.6.5.4 EPA ELCC Profiling. The EPA developed criteria to evaluate environmental methodologies or models to provide government and private organizations with an overall assessment of a particular model or methodology. They use the following list of criteria:

1. General Profile Information – provides basic information on the target audience, who developed the product, how much it costs, and the maturity / age of the product.

2. Application – provides information about the areas which the model or methodology can be used and the extent of which environmental information can be included in the analysis. It also determines if ELCC Models include financial analysis, environmental impact analysis, waste management / pollution prevention, environmental costs listing / database, cost estimation, and evaluation of alternate products / processes applications.

3. Summary of Methodology / Software – summarizes the functions and features of the model or methodology.

4. Life-Cycle Stages Covered – evaluates what life cycle stages are evaluated.

5. Types of Costs Considered – evaluates what environmental costs are considered.

6. Method of Cost Estimation – determines what type of cost methodology is used: analogy, parametric, engineering, and actual costs. These methods are described in Section 2.5.6.

7. Generation of Financial Indicators – evaluates if net present value, internal rate of return, payback period, or benefit/cost ratio is calculated.

8. Attributes and Limitations – lists general attributes and limitations of the product. (34, 2.4-2.8)

2.6.6 ELCC Methodology and Model Difficulties. ELCC methodologies and models have not gained complete acceptance by both government and civilian managers because of the difficulties associated with ELCC methodologies and models. The next six sections will summarize the different DoD ELCC methodology and model difficulties that face acquisition professionals and managers today. These difficulties were developed from studying and working with ELCC methodologies and models and by talking to acquisition environmental and financial experts. Most of these ELCC methodology and model difficulties are related to the cost estimating methodology guidelines and LCC model criteria presented in Sections 2.5.8 and 2.6.5.

2.6.6.1 General Issues. Many general issues create difficulties with DoD ELCC methodologies and models. These issues make it difficult for individuals to properly communicate or present a proper environmental analysis to others. Here is a list of these problems, a brief description, and an example or explanation of each one:

Oversimplification – DoD acquisition professionals fail to include all necessary costs when evaluating a technology or process with an ELCC methodology or model. This is a common concern in DoD especially when trying to decide what are the appropriate environmental costs associated with a particular chemical or material for a piece of aerospace equipment. A program analyst might only look at the procurement cost of the material, but fail to evaluate other process, operation, maintenance, logistic or environmental costs. This happens for several reasons: the complexity of the weapon system might make it difficult to determine these costs or factors, environmental cost data

might not be available or difficult to find, or the analyst does not completely understand the technology or process.

Developer / user interaction – ELCC methodology and model developers and users fail to properly communicate important methodology and model details (instructions, assumptions, etc.) with each other. Most DoD ELCC methodologies and models are developed by contractors hired by a specific weapon system program to evaluate certain environmental technologies, options, or processes. Once the ELCC methodology or model is complete, the developer (contractor) turns the final product over to the user (DoD weapon system program) and the contract is complete. The turnover usually consists of an instruction manual, presentation, report, and / or training course explaining how the ELCC methodology or model evaluates the different environmental technologies, options, or alternatives. The problem occurs after the turnover when the DoD weapon system program uses the ELCC methodology or model incorrectly because they do not have the proper training or cannot receive the necessary instruction without additional cost.

Lack of understanding / knowledge – individual does not have the technical background or knowledge to completely understand or correctly use the DoD ELCC methodology or model. This problem can occur when essential information describing the ELCC methodology or model is not available or understandable to the user. Another cause of this problem is when the ELCC methodology or model user does not have the time or fails to read the instruction manual. The result of these two situations usually causes the user to use the ELCC methodology or model incorrectly, inappropriately, or inaccurately. An example of this problem is a financial analyst using an ELCC

methodology or model to evaluate the cost of new environmental technology, but does not understand the materials and processes associated with the new environmental technology. The financial analyst might have a strong financial background, but cannot effectively evaluate the ELCC of a weapon system program because of a lack of environmental knowledge. Another example of this problem is an environmental analyst using an ELCC methodology or model to evaluate the cost of new environmental technology, but does not understand DoD financial procedures and regulations for weapon system programs. The environmental analyst might have a strong environmental background, but cannot effectively evaluate the ELCC of a weapon system program because a lack of a financial knowledge.

No standardized framework – some DoD organizations develop and use their own ELCC methodologies and models. These ELCC methodologies and models consist of different assumptions, definitions, algorithms, and data making it difficult to present or communicate information with somebody not intimately involved with that specific ELCC methodology or model. An example of this is the three existing DoD ELCC methodologies and models presented in Section 2.6.2.2. Each one of DoD ELCC methodologies and models have completely different purposes, uses, assumptions, definitions, algorithms, and data making it nearly impossible to compare results.

Assumptions – all DoD ELCC methodologies and models have assumptions to achieve a certain purpose or use as described in Section 2.6.2. When using a DoD ELCC methodology or model, the user must understand the assumptions to perform the environmental analysis properly. If a user fails to properly incorporate all necessary assumptions, the conclusions or decisions derived from the model could be incorrect.

Individual Bias – individuals do not think alike. Professionals disagree for different reasons. They might disagree because of different backgrounds (environmental versus financial) or opinions (assumptions, costs, processes, etc). DoD acquisitions is a diverse organization with numerous expert personnel with professional differences.

2.6.6.2 Laws and Policies. Another difficulty with ELCC methodologies and models is accounting for all the environmental laws and policies that affect weapon systems. This difficulty can be divided into three categories: lack of understanding, locality differences, and prediction problems. Each one of these categories will be discussed in more detail.

International, federal, state, and local environmental laws and policies can play a major role in the ELCC of a Weapon System. These environmental laws and policies can be complex and difficult to understand. All international, federal, state, and local environmental laws and policies have different nuances, procedures, or statutes and sometimes they even conflict with each other. This problem is then compounded because most DoD weapon system programs do not have an environmental law or compliance expert to help translate these issues so that an ELCC methodology or model can evaluate the associated costs.

Weapon systems are deployed all over the world. International, federal, state, and local environmental laws and policies create different environmental requirements and costs. Basing an F-16 in South Carolina generates different requirements and costs when compare to basing it in Georgia or Germany. For example, South Carolina might regulate a certain chemical (e.g. hydrazine) and require special handling and disposal

procedures. However, Germany might not regulate that certain chemical and DoD can use cheaper handling and disposal procedures.

It is difficult to predict future laws and polices that might have an affect on a weapon system. It is nearly impossible to determine the cost if a state or country decides to not allow a certain hazardous material into their territory in the future. An example of this problem is the development of the B-52. No major environmental laws existed in 1940s and 1950s when the B-52 was developed. Now there are thousands of environmental laws that B-52 support organizations must comply with even though the weapon system was developed before the laws existed. Had the B-52 project office tried to calculate the ELCC in the early stages of their program, results would have been grossly incorrect.

2.6.6.3 Complexity. Methodologies and models are used to simplify complex problems. Determining the ELCC of a weapon system is complex because of the numerous performance factors (e.g. speed, visibility, sound, etc.), systems (e.g. support, propulsion, fuel, avionics, structure, etc.), processes (e.g. coatings, electroplating, maintenance etc.), organizations (e.g. acquisitions, operation, support, logistics, etc.), and personnel (e.g. engineering, environmental, cost, communication, medical, etc.) involved. Changing one of these factors can have significant impact on the rest.

The decision to use an environmentally hazardous or friendly paint for a tactical fighter aircraft illustrates this problem. First, the analyst determines if both paints meet performance specifications required for the different systems – proper corrosive protection, camouflage, radar protection, etc. Then the analyst determines what processes it will change - how often paint must be applied, what type of facilities are

needed, how much energy will be saved, can the work be completed at the base or a depot, etc. Then the analyst must evaluate how it will effect different organizations and personnel – can any organizations be cut out of the process, how many personnel are needed to do the job, what type of personnel protection equipment must be used, etc. These are just some of the issues that must be evaluated when completing the ELCC of different paints for a tactical fighter aircraft.

2.6.6.4 Data. One of the biggest difficulties with DoD ELCC methodologies and models is the data required to use them properly. Collecting, generating, analyzing, and managing environmental cost data can require an extensive amount of time and a significant amount of funding. Once the environmental cost data collection is complete, DoD weapon system programs must organize and continually maintain the data to keep it current. Environmental cost data must also be analyzed each time before it is used to ensure that it is applicable when trying to determine future costs or decisions. Finally, historical data is not always applicable when new technologies are being evaluated.

An example of this problem is trying to calculate the ELCC of the JSF. Current environment cost data exists for aircraft of a similar nature (F-15, F-16, or F-22), but these aircraft use different chemicals, materials, processes, and procedures. Even if they did have the same chemicals, materials, processes, or procedures, the data would still have to be adjusted for different quantities, locations, methods, or contract and support organizational costs. The JSF Program could estimate future values for environmental cost data in all phases of the life cycle; however, an extensive amount of time and/or significant amount of funds might be required to develop this data. This might not necessarily provide accurate information because the JSP has many new technologies that

have never been fielded before. These problems could lead a young acquisition program to not develop an ELCC model or methodology because the cost or time investment is considered too high or the results might be considered unreliable.

2.6.6.5 Time. Time is another difficult issue with ELCC methodologies and models because most weapon systems have a 30 to 50 year life cycle from concept design until ultimate disposal. It is difficult to predict a weapon system's effective life, future roles, or new technology developments. Again the B-52 provides an example why time creates a problem for determining the ELCC for weapon systems. The B-52 became operational in the mid-1950s with an original mission as a long range, high altitude, intercontinental nuclear bomber using different control systems. Since that time, the B-52 has seen several modifications that have changed the mission and technologies it uses. The B-52 now carries cruise missiles and smart munitions using computer guided navigational systems. The B-52 is expected to remain in the Air Force inventory for another 40 years. It would have been impossible to calculate a reasonable ELCC for the B-52 in the mid-1950s. Environmental laws and policies were almost nonexistent at time, and no one could have predicted that computers and missile / munitions technology would have developed so fast.

2.6.6.6 Integrating the ELCC into the overarching LCC. A reason why ELCC methodologies and models are not used extensively in DoD is the perception that the ELCC of a weapon system program is a relatively minor cost when compared to other weapon system program costs. Most LCC estimates only evaluate significant cost drivers (e.g., engine, structure, etc.) and do not take into account minor cost details (e.g., environmental, lubrication, mechanical fasteners, etc.). Environmental costs might also

already be calculated into the LCC but not specifically broken out because they are only small portion of the estimate. For example, new aircraft hangers constructed for a weapon system program are planned or designed so that they address environmental compliance requirements. The overall LCC of the new aircraft hangers are accounted for in the LCC estimate and include most costs associated with environmental compliance requirements. However, the specific ELCC associated with the environmental compliance requirements associated with the new aircraft hangers are not specifically broken out because they are only a fraction of the overall LCC. Therefore, it becomes difficult to integrate the relatively minor environmental costs developed by ELCC methodologies or models into the total cost developed by the overarching LCC methodology or model that does not specifically break out environmental costs.

In addition, ELCC methodologies and models are not widely accepted because the ELCC results are not easily integrated into the overarching LCC. Environmental cost is only one of many factors facing a program manager who must evaluate different alternatives. The program manager must look at several different factors (performance, speed, etc.) and costs (material, production, operation, procurement, etc.). Therefore, for an ELCC methodology or model to be more effective, the results need to integrate into the overarching LCC. This will allow program managers to make more informed decisions because they can evaluate what effect environmental factors have on the other components of the weapon system.

2.7 Summary

This chapter began with a brief background on the impact of environmental costs to the Department of Defense (DoD). It pointed out that DoD environmental costs are significant, approximately $4.0 billion a year, and roughly 70% of these costs are directly attributed to weapon systems. This chapter then summarized the weapon system acquisition process, environmental requirements, and cost information. It explained that determining the ELCC of a weapon system is difficult because the complexity of the DoD acquisition bureaucracy, environmental policy and regulations, and cost accounting procedures. The final section reviewed current ELCC methodologies and models (i.e., the Army ELCC Methodology, Navy ELCC Model, and NDCEE ECAM), discussed their purpose and uses, examined methodology and model evaluation techniques, and analyzed the difficulties of using or adopting an ELCC methodology and model.

III. Methodology

3.1 Introduction

This chapter details the methodology used to provide Department of Defense (DoD) weapon system program managers insight to current environmental life cycle cost (ELCC) methodologies and models. A 3-step process is used to accomplish this task. The first step of this methodology will investigate the importance of developing an ELCC methodology or model for a weapon system program. Senior governmental officials want this information, as demonstrated by laws, policies, and testimony. Other government and private organizations have successfully developed and used their own ELCC methodology or model. Justification will then be provided to show that it is worth a weapon system program's time and effort to determine and document its ELCC. The second step is to develop a list of standardized environmental cost categories that DoD weapon system managers should track. Several DoD weapon system programs categorize environmental costs differently and this can create some confusion when calculating the ELCC of a weapon system. Defining environmental cost categories also provides a means to evaluate the different DoD ELCC methodologies. The third and final step will specifically evaluate three existing DoD ELCC methodologies. These methodologies will be evaluated using a set of DoD ELCC methodology assessment criteria developed from several LCC experts. Providing this information will demonstrate how some DoD weapon system program managers analyze the ELCC of their programs.

3.2 Importance of a DoD ELCC Methodology or Model

It is important to establish why DoD should pursue developing an ELCC methodology or model. This section will attempt to justify why a DoD weapon system manager should implement an ELCC methodology or model. The first part of this section will reemphasize the importance of Public Law 103-337, Section 815 and how it requires DoD to calculate the ELCC for all major weapon systems. The second part will explain the importance of determining the ELCC of a weapon system by providing testimony from senior governmental officials and recently proposed DoD environmental policy. The third part will provide specific examples of several organizations, both military and civilian, that use different ELCC methodologies or models. It will also summarize their successes, failures, and other findings. Finally, this section will explain the advantages and disadvantages of implementing an ELCC methodology or model in DoD weapon systems. It will demonstrate that knowing the ELCC of DoD weapons systems is worth the cost of gathering and estimating the data.

3.3 Determination of Standardized Environmental Cost Categories

To evaluate the ELCC of a DoD major weapon system, environmental cost categories must be clearly defined. This section will define environmental cost categories associated with DoD major weapon systems. A benchmarking approach will be used to develop a standardized list of environmental cost categories for DoD. Section 3.3.1 provides a list of assessment criteria used to determine how well an organization categorizes their environmental costs. Section 3.3.2 describes which DoD organizations' environmental cost categories will be evaluated and how they will be compared. By

analyzing how several different organizations categorize their environmental costs, a comprehensive list of environmental cost categories can be developed to ensure the most significant environmental costs are properly accounted. Finally, these environmental cost categories will be organized into a WBS format that takes into account different DoD appropriations or acquisition phases to follow the current DoD costing techniques.

3.3.1 Assessment Criteria for Environmental Cost Categories. For an ELCC methodology or model to be effective, it must track all significant environmental costs and organize them in a manner that allows for effective analysis. A DoD ELCC methodology or model must include environmental cost categories that include all applicable environmental costs, organize cost information in a WBS format that includes the appropriate DoD appropriations and acquisition phases, and provide useful information. Therefore, the following criteria should be used when analyzing an organization's environmental cost categories:

Inclusiveness – the environmental cost categories include all applicable environmental costs associated with a weapon system and subsystems.

Compatibility – the environmental cost categories incorporate a WBS format that includes the appropriate DoD appropriations and acquisition phases.

Categories – the environmental cost categories are defined and organized so that a program manager can analyze the cost figures to make smart references or decisions.

3.3.2 Evaluation of Existing DoD Environmental Cost Categories. The environmental cost categories used by the Army, Joint Strike Fighter (JSF) Support Office, and DoD Evaluation Report will be analyzed and compared. Using the

assessment criteria developed in Section 3.3.1, it will be determined how each organization individually categorizes their environmental costs. Then data from each analysis will be organized into a table and compared. This comparison will point out the positives and negatives of each organization's environmental cost categories and provide a template that can be used to develop a standardized set of environmental cost categories for DoD.

3.4 Evaluation of Existing DoD ELCC Methodologies and Models

This section will evaluate the Army ELCC Methodology, Navy ELCC Model, and NDCEE ECAM presented earlier in Section 2.6.3.2. To evaluate these DoD methodologies and models, assessment criteria must be developed. Section 3.4.1 evaluates and categorizes four separate sets of methodology and model assessment criteria developed by LCC experts. Section 3.4.2 then lists and defines the assessment criteria that will be used to evaluate the three different DoD ELCC methodologies and models.

3.4.1 ELCC Methodology and Model Assessment Criteria. In Section 2.6.5, four sets of methodology and model assessment criteria were presented. The assessment criteria from these four sets can be grouped into the following six categories: background, completeness, sensitivity, data, operation, and other. Table 3.1 shows all the assessment criteria from the four sets presented Section 2.6.5 and organizes them into the six common categories. The importance, specifics, and ambiguities of each methodology and model assessment category will be summarized and evaluated.

Table 3-1. Methodology and Model Assessment Criteria Categories.

CATEGORIES	AFSC/AFLC	SHELDON	ASC/FM	EPA
Background		• Economy • Speed • Ease of operation		• General profile info • Application • Summary of methodology / model • Attributes and limitations
Completeness	• Completeness	• Usefulness throughout a program • Inclusiveness • Program and design sensitivity	• Completeness • Consideration of design objectives	• Life cycle stages covered • Types of costs considered
Sensitivity	• Sensitivity	• Sensitivity analysis	• Sensitivity	
Data	• Availability of data	• Feasible data requirements • Economic capability and flexibility	• Availability of input data	• Method of cost estimation • Generation of financial indicators
Output	• Documentation	• Transition to detailed quotation • Authoritative	• Documentation • Validity • Analysis results	
Other		• Variable learning curve • Tolerance and helpfulness • Modular format • Security		

The Background assessment criteria category is the most overlooked category. Only two of the methodology and model criteria sets provide any guidance. This category is probably the most important category to detail because of the basic information it provides. Before a methodology or model is selected, it is important to know to the using organizations, developer, development date, applications, functions and features, associated costs, attributes and limitations, and ease of operation. Without

this information, it is difficult to effectively determine if a methodology or model will be useful to an organization. This information is also important for the selection of an ELCC methodology or model.

The Completeness assessment criteria category is one of the most common among the four different sets of methodology and model assessment criteria. This shows the need that a methodology or model should account for all important relevant information and data. In the case of a DoD ELCC methodology or model, it is important to ensure that all appropriations, acquisition phases, environmental costs, and alternatives are effectively and equally accounted.

The Sensitivity assessment criteria category is included in three of the four sets of methodology and model assessment criteria. This shows the importance of evaluating different factors or financial indicators that might have a significant effect on which alternative an organization might select. This criterion is also important for a DoD ELCC methodology or model because of the complexity of environmental costs associated with weapon systems and organizations.

The Data assessment criteria category is also one of the most common among the four different sets of methodology and model assessment criteria. Data generation and collection play a large role in the effectiveness of a methodology or model. Data sources must be available and accurate for a methodology or model to be accepted. Methodology and model users must also know if cost estimates are from an analogy, parametric, engineering, or actual estimate. This criterion is also important when evaluating a DoD ELCC methodology or model because of the different factors, processes, materials,

chemicals, professionals, organizations, and systems that generate environmental cost data that must be accounted for to determine the ELCC of a weapon system.

The Output assessment criteria category is also included in three of the four sets of methodology and model assessment criteria. This shows the importance of documentation and acceptance of the output generated by a methodology or model. This criterion is important for assessing a DoD ELCC methodology or model because different professionals and senior leaders must accept and approve the output that is generated to include it in their decision making process.

The Other assessment criteria category only contains outlying LCC methodology and model assessment criteria from Sheldon. These criteria deal with the computer system that would run a LCC methodology and model. Therefore, these criteria will not be evaluated because they are not within the scope of this thesis effort.

3.4.2 DoD ELCC Methodology and Model Assessment Criteria. This section will provide the set of assessment criteria that will be used to evaluate each DoD ELCC methodology or model. The DoD ELCC methodology and model assessment criteria are based on the cost estimating methodology guidance from Section 2.5.8 and the evaluation of the methodology and model assessment criteria in Section 3.4.1. The DoD ELCC methodology and model assessment criteria are broken into five categories (background, completeness, sensitivity, data, and output). Each criterion is also broken down into several sub-criteria. A definition or short explanation is provided for each of the sub-criterion.

3.4.2.1 Background Assessment Criteria.

General Profile Information – provides basic information on what organizations can use the methodology or model, who developed the methodology or model, and how long the methodology or model has been used.

Application – provides general information on the methodology's or model's ability to provide financial analysis, environmental impact analysis, waste management / pollution prevention, environmental costs listing / database, cost estimation, and evaluation of alternate products / processes applications.

Summary of Methodology or Model / Software – summarizes the functions and features of the methodology or model.

Ease of use – evaluates the amount of training required, information needed, and time necessary to complete an ELCC estimate.

Economy - evaluates the developmental, procurement, implementation, operation, or modification costs of the ELCC methodology or model. For example, developmental costs are the expenses required to develop an ELCC methodology or model to track environmental costs associated with a weapon system program. Procurement costs are the funds required to purchase hardware or software needed for an ELCC methodology or model. Implementation costs are the expenses required to generate data (i.e., hazardous material quantities, environmental costs, etc.) needed by the ELCC methodology or model for the specific weapon system program. Operation costs are the expenses associated with the daily operational use of the ELCC methodology or model. Modification costs are the funds required to change the ELCC methodology or model to meet different needs required by the user.

Attributes and Limitations – lists general attributes and limitations of the product.

3.4.2.2 Completeness Assessment Criteria

Life Cycle Stages Covered – evaluates if the methodology or model analyzes all Weapon System acquisition life cycle stages.

Types of Costs Considered – evaluates what environmental costs are considered. These costs will then be compared to the list environmental cost categories developed in Section 4.3.4. Then it will be determined if the environmental costs include the appropriate DoD appropriations and if they are organized in a WBS format.

3.4.2.3 Sensitivity Assessment Criteria

Sensitivity Analysis - does the methodology or model consider specific design or program parameters so that ELCC differences among alternatives can be evaluated?

Generation of Financial Indicators – evaluates if net present value, internal rate of return, payback period, or benefit/cost ratio is calculated.

3.4.2.4 Data Assessment Criteria

Data availability and sources – evaluates the availability, accuracy, and organization of the data needed to determine the ELCC.

Method of Cost Estimation – determines what type of cost estimate is used: analogy, parametric, engineering, and actual costs.

3.4.2.5 Output Assessment Criteria

Validity – evaluates if the output represents the real-world environment, provides output results that can be used to serve as a valid and logical basis for selecting an alternative or option, and is accepted by higher management.

Documentation – evaluates if the results are presented in a way that can be quickly reviewed and understood by others.

IV. Weapon System Environmental Life Cycle Cost Analysis

4.1 Introduction

This chapter will follow the methodology prescribed in Chapter 3. First, it will determine the importance of implementing a DoD Environmental Life Cycle Cost (ELCC) Methodology or Model. Second, it will evaluate existing environmental cost categories used by some DoD organizations and then develop a standardized set of environmental cost categories for DoD. Finally, it will evaluate the Army ELCC Methodology, Navy ELCC Model, and National Defense Center for Environmental Excellence (NDCEE) Environmental Cost Analysis Methodology (ECAM).

4.2 Importance of a DoD ELCC Methodology or Model

This section will evaluate the implementation and use of an ELCC methodology or model in a DoD weapon system program. The first part of this section will reemphasize the importance of Public Law 103-337 (Section 815) and how it requires DoD to calculate the ELCC for all major weapon systems. The second part of this section will then provide testimony from senior governmental officials explaining the importance and purpose of an ELCC methodology or model for major weapon systems. The third part of this section will provide specific examples of several organizations, both military and civilian, that use an ELCC methodology or model and summarize their experiences. Finally, this section will explain the reasons for implementing an ELCC methodology or model for DoD weapon systems and postulates that knowing the ELCC for DoD weapons systems is worth the costs of gathering and estimating the data.

4.2.1 Public Law 103-337, Section 815. Public Law 103-337 states that the Secretary of Defense shall implement uniform guidance throughout DoD to analyze the life cycle environmental costs for all Major Defense Acquisition Programs (MDAP). DoD currently does not have a uniform standard to analyze life cycle environmental costs, because each service is attacking this problem in a different manner. The Navy is developing an ELCC cost model, the Army has developed an environmental work breakdown structure, and the Air Force analyzes environmentally regulated chemicals and materials on an individual basis for their MDAP. Note: the Air Force has recently started to implement the ELCC model the Navy is developing.

It can be argued that it is difficult to develop a uniform standard when each service has completely different programs, issues, or needs. However, the intent of the Public Law is for DoD to be able to capture the significant environmental costs, improve strategies to reduce or eliminate these costs, and develop a baseline to evaluate improvement. Obviously, Congress feels that analyzing the ELCC of MDAP is necessary and a good business practice for DoD. Therefore, to meet the intent of the Public Law, DoD should at a minimum provide guidance that would allow each service to document and evaluate life cycle environmental costs in a uniform manner.

4.2.2 Senior Governmental Official Testimony. Numerous senior government officials have stated through hearings, speeches, reports and proposed policies that evaluating and reducing the impact of environmental costs of DoD weapon systems are important. What follows are some brief exerts from a Senate Armed Services Subcommittee (Readiness) hearing, statements from Defense Secretary William Cohen

and Undersecretary Sherri Goodman (Environmental Security), and newly proposed policy from a DoD ESH Acquisition Integrated Process Team (IPT).

In a Senate Armed Services Subcommittee (Readiness) hearing held on 26 April 2000, Senator Levin asked Dr. Gansler "Would you agree that environmental costs are an essential element of program LCC…?" and wanted to know how they are tracked for weapon system programs. Dr. Gansler replied, "I agree that environmental costs are an essential element of program LCC costs..." and specifically sited the following sentence from DoD 5000.2R, "...the PM shall regularly review ESOH regulatory requirements and evaluate their impact on the program's life cycle cost, schedule, and performance." Dr. Gansler also pointed out that DoD needs "...to consistently account for environmental costs..." and "...update policy and procedures ... to improve DoD's accounting of environmental costs in life-cycle estimates." DoD needs to develop an ELCCM to consistently track environmental costs to find ways to reduce them. (42)

Secretary Cohen and Undersecretary Goodman have made numerous statements testifying that DoD needs to reduce environmental costs so saved money can be spent on other programs, such as modernization, operations, etc. In a speech on 27 April 1998, Secretary Cohen stated, "Protecting the environment is also a budget and management issue. Preserving and conserving where we can today means spending less money on cleanup and compliance costs tomorrow (3, 1)." In a report submitted on 13 April 1999, Undersecretary Goodman stated, " (DoD must integrate) environmental considerations into the development, maintenance, and upgrade of weapon systems to protect the health and safety of our personnel, improve operational performance and reduce life cycle costs" (20, 2)

In October 2000, the DoD ESOH Acquisition Integrated Process Team made numerous recommendations to revamp the existing DoD policies on ESOH issues. One of the most significant recommendations they made dealt with ELCC. This recommendation specifically requests that environmental compliance costs be included in the Acquisition Program Baseline (APB), a document that specifies the overall cost, schedule, and performance factors of a weapon system program. (25, 1-3)

These hearings, speeches, reports, and newly proposed policies show the significance of environment costs to DoD officials. These senior governmental officials believe that too much money is spent on environmental cleanup and compliance and want long-term solutions. To reduce these environmental costs, DoD should develop a standardized methodology or model to help weapon system programs track their ELCC. This methodology should provide the basic framework for an ELCC estimate, but allow some flexibility to meet the specific needs of a weapon system program. Weapon system programs would then have a standardized management tool to track and analyze the progress of reducing their overall environmental cost burden. DoD could then require each weapon system program to present their ELCC estimates at each milestone to ensure they are pursuing a long-term strategy.

4.2.3 ELCC Case Studies. This section will look at several ELCCM case studies from different organizations. Each case study will be summarized and the main findings will be presented. The case studies are grouped into three categories: EPA, Boeing, and Military. Each category will be summarized and then analyzed to determine the importance to DoD.

4.2.3.1 EPA Case Studies. Over the past five to ten years, the EPA has documented how several different organizations and industries developed their environmental accounting (EA) procedures. EA is synonymous with ELCC. This section will summarize several EPA Case Studies where EA or ELCC was successfully used by private industry.

4.2.3.1.1 Electroplating Operations. In May 1997, the USEPA Office of Pollution Prevention and Toxics completed an 18-month investigation on the application of EA practices in the electroplating industry. This research analyzed 24 on-site electroplate captive operations (electroplating included as part of a larger manufacturing process) or job shop facilities (specializing in providing electroplating services to manufacturers). The focus of this study to determine how EA can help capital budget decisions and target improvements in the electroplate industry. (28, 1)

This study determined the five greatest environmental costs to the electroplating industry are wastewater treatment, hazardous waste disposal, sewerage, plating chemistry loss, and other process solution loss. The study found that the chemistry and solution loss was the most significant cost. This cost is usually unrecognized because it has repercussions elsewhere in the organizations environmental cost structure (i.e. indirect labor caused by permits, reports, manifesting, etc.) and the "true" cost of its waste went beyond disposal and wastewater treatment costs. This study also produced the following findings:

- Many organizations use EA practices, but do not know or call it that. Many "conventional" costs (e.g. wastewater treatment operations, hazardous waste disposal, etc.) associated with the environment are recognized and captured in traditional accounting methods.

- EA allows organizations to find "hidden" costs and provides a more robust and accurate economic evaluation of projects.

- All types of environmental costs can be derived, but the organization must decide what level of information will provide them with the maximum benefit.

- Environmental management costs that do not directly affect payroll and payables (e.g. labor costs of preparing permits or manifesting) are typically left out of evaluations.

- Gathering and tracking environmental costs poses an obstacle because finding the proper information at a level of detail as necessary to analyze a process can be expensive.

- Allocating costs to processes responsible for generation can be difficult. Typically costs are allocated by estimates (i.e. square feet processed, hours of operation, etc.) or professional judgement.

- EA is a valuable tool, but is must be used with other accounting practices to provide a complete analysis. (28, 1-6)

<u>4.2.3.1.2 Chemical and Oil Companies</u>. In 1996, the USEPA Environmental Accounting Project conducted a benchmarking study of five major US and Mexican oil and chemical companies involved in developing EA systems. The purpose of this benchmarking study was to compare the EA practices of oil and chemical organizations that have a significant impact on the environment. The study discusses how they track environmental costs and the uses of the information it provides. (29, 3)

The environmental culture at most oil and chemical companies is changing from compliance driven to prevention or profit oriented by striving for economic success, social responsibility, and environmental stewardship. These companies are starting to implement additional dedicated ESH management positions to their organizations and develop more integrated environmental cost structures that track more specific information (i.e. safety, remediation, hazardous waste, medical services, etc.). By

identifying and quantifying environmental costs, these companies hope to improve the following decision opportunities:

- Internal / External Benchmarking - the ability to compare different production plants, facilities, or against competitors.
- Product Pricing – knowing environmental costs can help determine a better understanding of the cost of a particular product or process.
- Product Mix – knowing environmental costs can help determine which products will produce the maximum profit.
- Waste Management Decisions – cost effective choices can be made when all environmental costs are known.
- Pollution Prevention Alternatives – better capital expenditure decisions are made with the knowledge of environmental costs.
- Materials / Supplier Selection – evaluating the products from "cradle to grave" pushes environmental responsibility up the supply chain and reduces environmental compliance or restoration costs.
- Facility Location / Layout – combining, sharing, or relocating facilities can help reduce environmental costs.
- Outbound Logistics – must understand the environmental effects of packaging, transporting, and disposing of products.
- Market-Based Environmental Options – must understand the market of environmental allowances (i.e. SO_2 air emissions) and how to reduce their costs.
- International Environmental Standards – must be able to understand and comply with ISO 14000 standards to maintain a customer base in areas that might require this standard in the future.
- Public Relations / Lobbying – knowing environmental costs can help determine strategies and decisions to avoid future problems.
- Training – must be able to determine what training is necessary and determine the economic way to meet requirements. (29, 4:34)

4.2.3.1.3 Ontario Hydro. In May 1996, the USEPA Environmental Accounting Project completed a case study that illustrates Ontario Hydro's, the biggest power utility in North America (in terms of installed generating capacity), "Full Cost Accounting" (FCA) procedures. According to Ontario Hydro:

> FCA is a means by which environmental considerations can be integrated into business decisions. FCA incorporates environmental and other internal costs, with external impacts and costs/benefits of Ontario Hydro's activities on the environment and on human health. In cases where the external impacts cannot be monetized, qualitative evaluations are used. (33, 6)

The implementation of FCA allowed Ontario Hydro to contain costs, stabilize electricity rates, and gain greater efficiency by clearly accounting for its all activities, costs, and environmental performance. (33, 4-5) The Ontario Hydro Case Study provided the following feedback on FCA:

- Must demonstrate that FCA makes "good business sense" to get organizational buy-in. Organizational members must see the value of knowing environmental costs and understand the potential impacts.
- It is difficult for an organization to start calculating environmental costs.
- Must have executive buy-in to implement FCA effectively.
- FCA is not a decision-making process. FCA allows decision-makers to integrate environmental issues into business decisions.
- FCA cannot be implemented overnight. FCA requires a organizational culture change. Implementing FCA is a long, slow process that will help organizations become more competitive.
- FCA requires employees from several different disciplines (i.e. environmentalists, accountants, etc.).
- FCA requires common terminology for multi-disciplinary employees to understand each other. These individuals must be trained in FCA to implement it to its fullest potential.

- Data must be accurate and analyzed consistently for it to be useful for decision-making. (33, 38-40)

4.2.3.1.4 AT&T. In September 1995, the USEPA Office of Pollution Prevention completed a case study that illustrates AT&T's "Green Accounting" procedures. AT&T defines Green Accounting as:

> Implementing and measuring the costs of environmental materials and activities and using this information for environmental management decisions. The purpose is to recognize and seek to mitigate the negative environmental effects of activities and systems. (30, 3)

AT&T implemented Green Accounting because of a desire to strike a balance between business interests and environmental protection. AT&T believes that investing in the environment can reduce operational costs, avoid future liabilities, and increase customer support. (30, 4:12) AT&T used Green Accounting to accomplish the following tasks:

- Developed a glossary of terms that allowed different professionals to communicate and track environmental costs more efficiently. This also helped spread environmental awareness throughout the organization.

- Used Activity Based Costing to evaluate environmental costs. This provided management information on the total costs and their "cause" drivers. With this information, management could then make decisions that would either reduce the cost or reduce / eliminate the "cause" driver.

- Developed a baseline to determine the environmental costs of every product. This led to a better understanding of their procedures with environmental costs and provided information that could be used to evaluate progress. (30, 19-25)

4.2.3.1.5 EPA Case Study Analysis. Individually, the companies and industries associated with these case studies do not compare to the magnitude of a DoD weapon system program. What makes these case studies significant is that DoD weapons system programs have electroplating, chemical and oil, power production, and

management operations and organizations. These case studies describe similar difficulties DoD is currently facing and point out some potential benefits.

These organizations described some of the problems they faced implementing an ELCC methodology or model. These problems are similar to the problems DoD is facing today. Here is a summarized list of the problems compiled from the EPA case study organizations and industries when implementing an ELCC methodology or model:

- Many organizations account for their environmental costs with traditional accounting methods, but cannot specifically point these costs out because they are combined with other conventional costs.

- All types of environmental costs can be derived, but the organizations must decide what level of information will provide them with the maximum benefit.

- Environmental management costs that do not directly affect payroll and payables (e.g. labor costs of preparing permits or manifesting) are typically left out of evaluations.

- Gathering and tracking environmental costs poses an obstacle because finding the proper information at a level of detail as necessary to analyze a process can be expensive.

- Allocating costs to processes responsible for generation can be difficult. Typically costs are allocated by estimates (i.e. square feet processed, hours of operation, etc.) or professional judgement.

Most of the ELCC methodology and model difficulties these organizations faced were overcome by implementing EA policies that employees understood and accepted. After implementing an EA policy, these organizations were able to better understand their environmental costs and develop strategies to effectively reduce them. DoD could benefit from the practices that these organizations have found successful. Here is a summarized list of ELCC methodology and model practices compiled from the EPA case studies that could benefit DoD:

- Allows organizations to find "hidden" costs and provides a more robust and accurate economic evaluation of projects.

- Improves the ability to compare different alternatives, materials, chemicals, processes, production plants, facilities, etc.

- Improves knowledge of environmental costs that help determine a better understanding of the cost of a particular product or process.

- Improves waste management decisions – cost effective choices are made when all environmental costs are known.

- Evaluates pollution prevention alternatives – better capital expenditure decisions are made with the knowledge of environmental costs.

- Improves materials / supplier selection – evaluating the products from "cradle to grave" pushes environmental responsibility up the supply chain and reduces environmental compliance or restoration costs.

- Enhances facility location / layout – combining, sharing, or relocating facilities helps reduce environmental costs.

- Adheres to international environmental standards – develops understanding and complies with ISO 14000 standards to operate in areas that might require this standard in the future.

- Improves public relations / lobbying efforts – knowing environmental costs helps determine strategies and decisions to avoid future problems.

- Develops training processes – determines what training is necessary and the most economic way to meet requirements.

- Provides management information on the total costs and their "cause" drivers.

4.2.3.2 Boeing Case Study. Boeing St. Louis conducted a study analyzing the best way to evaluate future environmental costs. This study indicated that millions of dollars were spent on developing ELCC models and gathering environmental cost data. These models tracked around 20 to 40 different environmental costs, but only 5 to 8 of these environmental costs (facilities, labor, medical, material, legal / liability, etc.) were

actually significant. Another problem identified the existing ELCC models and data, was that they were historical and did not accurately predict the future. Figure 3-1 depicts a graph developed by Boeing that shows how the historical cost data is less accurate than predicted costs when compared to the actual environmental costs. The study concludes an environmental expert can better predict near future environmental costs than a model because they have more knowledge of forthcoming environmental regulations and technologies. (44, 1-2)

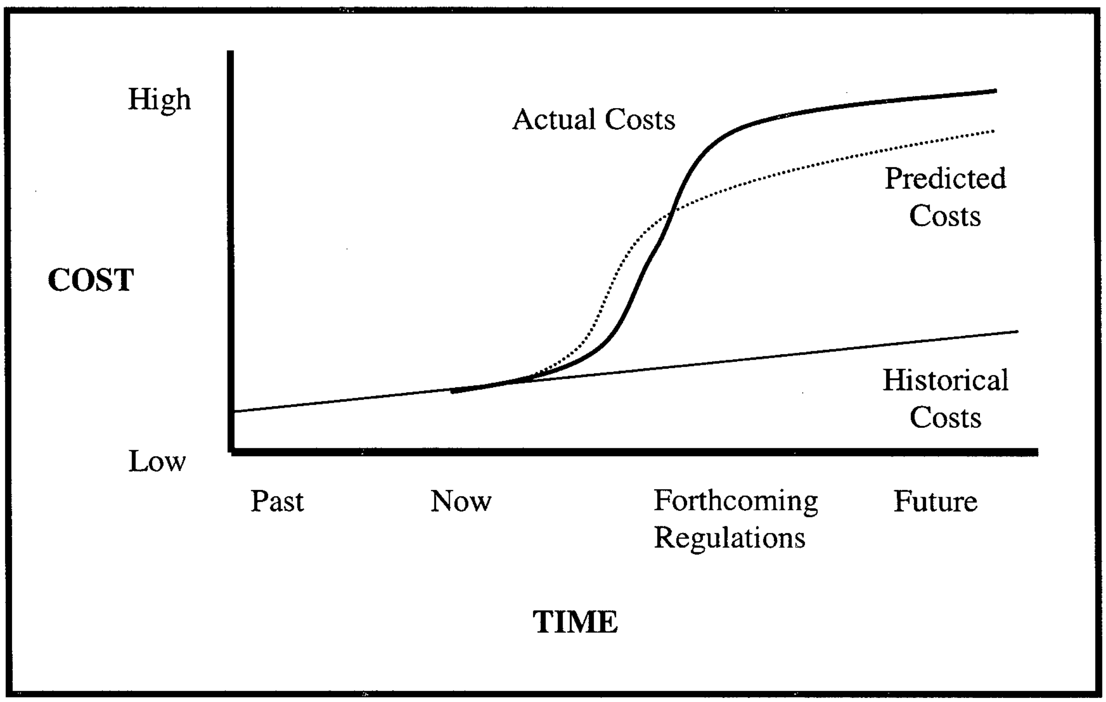

Figure 4-1. Environmental Life Cycle Cost Predictions (44, 1)

This study shows the importance of understanding and predicting future environmental costs for DoD weapon system programs. It also supports the value an ELCC methodology and not another historically based model to accurately predict future

environmental costs for weapon system programs. An ELCC methodology is important because it ensures that the most significant environmental costs are tracked, plus it can account for the implementation of future environmental law or policy changes. Another important feature of an ELCC methodology is that it provides standardized guidelines to help environmental professionals clearly organize all environmental cost information in a manner that will improve the communication process among different professionals.

4.2.3.3 Military Case Studies. Over the past six years, several DoD organizations have studied or used different ELCC methodologies or models procedures. This section will summarize four DoD Case Studies where ELCC methodologies or models were evaluated or used.

4.2.3.3.1 DoD Evaluation. In March 1995, the Capstone Corporation completed a project for the Office of the Director of Program Analysis and Evaluation that evaluated the environmental management cost estimating capabilities for MDAPs. This project was divided into three different phases. The first phase of the project identified and classified environmental management cost estimating and analysis tools. The second phase of the project developed a hierarchical WBS of environmental activities to a standard measure to assess the environmental management cost estimating tools. The third phase summarized the first two phases and then evaluated the environmental management cost estimating tools in the first phase with respect to the developed hierarchical WBS and then identified short and long-range plans. The first and second phases were conducted simultaneously and third phase was conducted subsequently. (21, 1)

The first phase of the project consisted of a literature review and a screening process. The literature review identified 71 different environmental management cost estimating tools from several sources (e.g. company brochures, computer magazines, environmental journals, etc.). Then a screening process was conducted to eliminate the environmental management cost estimating tools that were not directly applicable to DoD operations. The screening process selected the following seven environmental management cost estimating tools for full evaluation in the third phase of the project:

- Decommissioning & Decontamination (D & D) Cost Database
- Historical Cost Analysis System (HCAS)
- Hazardous Materials Life Cycle Cost Estimator (HAZMAT)
- Micro-Computer Aided Cost Estimating Support System (M-CASES)
- Remedial Action Cost Engineering and Requirements (RACER-ENVEST)
- Superfund Cost Estimating Expert (SCEES)
- Systems Cost Model (SCM)

The names of these environmental management cost estimating tools were provided for information only; specific details will not be provided in this document. (19, 1:27)

The second phase of the project selected the following five major environmental cost categories to evaluate the environmental management cost estimating tools:

1. Environmental Program Management
2. Hazardous, Toxic, and Radiological (HTR) Material Management
3. HTR Waste Management
4. Environmental Restoration / Corrective Measures
5. HTR Material and Waste Transportation

Note: these environmental cost categories will be discussed in more detail in Section 4.3.3. These environmental cost categories were derived from the Interagency Cost Estimating Group, an ad-hog group with representatives from the Department of Energy, DoD, EPA, and other organizations. The purpose of this environmental WBS was to provide DoD program managers with a common environmental structure that can be used as a checklist or to analyze environmental management activities. (18, 1:24)

The third and final phase of the this project consolidated the information contained in the first two phases, evaluated the seven environmental management cost estimating tools, and developed short and long range plans for DoD weapon system programs. The evaluation of the seven environmental cost estimating tools demonstrated that DoD needed to develop plans to improve their environmental cost estimating and analysis tools. In general, the seven evaluated environmental management cost estimating tools did not account for the all phases of the acquisition life cycle or lacked the proper environmental cost data and estimating relationships. From this evaluation, short and long-range plans were suggested. The short-range plan called for the completion of the following two tasks:

- *Develop a comprehensive environmental estimate for a selected MDAP.* A comprehensive estimate of environmental costs of a MDAP would identify cost model problems and solutions, determine if the environmental WBS was appropriate, and ascertain environmental cost data requirements.
- *Develop a long-term data collection strategy.* A data collection strategy should be based on the comprehensive environmental estimate to help identify sources and identify environmental cost data.

The long-range plan called for the completion of the following two tasks in three or more years:

- *Develop a comprehensive environmental management cost estimating and evaluation system.* A system should be developed to provide program managers with a complete perspective of their weapon system environmental operations and costs.
- *Develop environmental cost tool maintenance, testing, verification, and validation procedures.* Procedures must be developed to ensure new environmental regulatory requirements, technologies, and cost data are accounted properly. (21, 1:40)

Currently, DoD has only partially implemented the short and long-term strategies recommended by this report. A few organizations have developed comprehensive environmental estimates for selected MDAP. From these environmental estimates, they have identified some cost model problems and solutions, developed environmental WBS, and ascertained environmental data requirements for a specific MDAP. DoD has not developed a long-term data collection strategy or implemented a comprehensive environmental management cost estimating and evaluation system for all MDAP.

4.2.3.3.2 Air Force ESH Cost Analysis Guide. In May 1998, Air Force Material Command (AFMC) contracted EES Systems, Inc. to developed the Air Force Environmental, Safety, and Health Cost Analysis Guide (AFESHCAG) to help cost analysts identify, treat, and use ESH costs in system decision making. The AFESHCAG has four main purposes:

1. Provide an overview of ESH management information

2. Identify major ESH activities over the life cycle of a weapon system

3. Review basic ESH cost estimating concepts and processes

4. Present several ESH cost estimating applications.

The information presented to address the first three purposes is similar to the information in the different sections in Chapter 2 of this document. The AFESHCAG presented five different estimating applications; this section will summarize the fighter aircraft application because it provides the best example how contradictory ELCC figures for a single weapon system can be calculated by using different methodologies. (7,1)

The fighter aircraft application was developed to show the magnitude of ESH costs in the Operating and Support Phase of a typical Air Force fighter aircraft. This application also shows that ESH costs can be calculated several ways leading to different cost figures. Data was gathered from an Air Logistics Center database and a General Accounting Office (GAO) report. The ESH cost of the typical fighter aircraft was calculated using two different methodologies. (7, FA1)

The first methodology used a typical fighter aircraft program's overarching WBS and estimated ESH costs specifically related to each WBS cost category. This methodology determined the ESH cost per aircraft is approximately $21,908. See Table 4-1 for details. (7, FA2)

The second methodology used detailed cost information extracted from the base where the typical fighter aircraft is stationed. This methodology determined the ESH cost per aircraft is approximately $45,603. See Table 4-2 for details. (7, FA3)

Table 4-1. Fighter Aircraft ESH Costs (7, FA2)

WBS Level 1	WBS Level 2	O & S Cost	ESH Cost
Mission Personnel	Operations (Aircrew)	81,911	328
Mission Personnel	Maintenance	480,918	1,443
Mission Personnel	Other Mission Personnel	85,749	857
Unit Level Consumption	Aviation POL	175,381	
Unit Level Consumption	Consumable Supplies	64,702	
Unit Level Consumption	Depot Level Reparables	238,533	3,459
Unit Level Consumption	Training Munitions	46,453	
Unit Level Consumption	Other Mission Support	437	
Depot Maintenance	Overhaul/Rework	33,143	961
Depot Maintenance	Other	147,734	4,284
Contractor Support	Other	180	
Sustaining Support	Replacement Support Equipment	41,081	
Sustaining Support	Mod Kit Procurement/Installation	55,202	552
Sustaining Support	Other Recurring Investment		
Sustaining Support	Sustaining Engineering	6,429	186
Sustaining Support	Software Maintenance	8,231	
Indirect Support	Personnel Support (Medical)	119,108	2,382
Indirect Support	Personnel Support (Training)	142,020	607.57
Indirect Support	Personnel Support (PCS)	16,468	
Indirect Support	Installation Support (BOS)	138,485	1,385
Indirect Support	Installation Support (RPM)	61,948	3,097
Indirect Support	Installation Support (IS)	146,072	
Disposal Average			2,365
Total Cost per Aircraft		2,090,186	**21,908**

The main difference between these two methodologies is their perspective - the first methodology is a top-down (higher management) estimate and the second methodology is a bottom-up (worker) estimate. Higher management evaluates the broad and overarching costs of the organizations and workers tend to analyze their day-to-day costs. Another difference is how the environmental cost categories are defined. For

example, the first methodology defines personnel with three categories for personnel (operations, maintenance, and others) and second methodology defines personnel with two (civilian and military). Finally, the last major difference is how the cost estimates were derived. The first methodology developed an engineering estimate from a environmental cost database generated by a depot that services several different bases; whereas, the second methodology generated an actual estimate of environmental costs that were associated with one specific base.

Table 4-2. Fighter Aircraft ESH Costs (7, FA3)

Cost Element	Cost
Environmental	
Compliance	
Contractor Environmental Services	643,106
Personnel	24,363
Real Property, Wastewater treatment	443,944
Conservation	
Contractor Environmental Services	504,598
Pollution Prevention	44,998
Defense Environmental Restoration	1,190
War Reserve Material	
Contractor Environmental Services	440,429
Contractor Hazardous Waste Management	60,000
Contractor Hazardous Waste Treatment	785,014
Safety	
Headquarters Level	
Personnel (Civilian (CIV))	30,745
Personnel (Military (MIL))	546,414
Temporary Duty (TDY)	30,677
Supplies/Equipment	489
Unit Level	
Personnel (CIV)	100,162
Personnel (MIL)	320,826
TDY	16,710
Supplies/Equipment	16,527
Training	2,887
Total Cost	4,013,079
Cost Per Aircraft	**45,603**

This example application reveals the magnitude of ESH costs, importance of ESH cost data, and need for a standardized ESH cost methodology or model. According to this example, typical Air Force fighter aircraft ESH costs account for approximately 1.05% to 2.18% of their Operation & Support Phase Cost. This example also demonstrates the necessity of having good ESH data and ESH cost methodologies to determine the actual ESH cost. As shown by this application, the ELCC of the fighter aircraft was calculated with different methodologies and environmental cost data. DoD needs good EHS data and a standardized cost methodology to prevent confusion and ensure the accuracy of their ELCC estimates. Knowing accurate weapon system program ELCC figures can provide insight to help develop new environmental strategies to reduce the total cost burden. (7, FA4)

4.2.3.3.3 Army Comanche and Apache Programs. The U.S. Army Environmental Center (USAEC) developed an ELCC estimate for both the Comanche and Apache Helicopter Program Offices in April 2000. The methodology USAEC used for this estimate is described in Section 2.6.3.2.1. After concluding this process, the Army was able to develop the following list of significant ELCC drivers that they can use to focus their future efforts in reducing environmental and total operating costs:

I. Research, Development, Test and Evaluation (RDT&E)
- A. Compliance, Plans, Permits, Reports, Tests & Assessments
    1. National Environmental Policy Act (NEPA) (ESH)
    2. Site Surveys
- B. Pollution Prevention/Waste Management
    1. Environmentally related Trade Studies
    2. Engineering/Other Change Proposal Implementations (for #1 above)
    3. Development of Hazardous Materials Management Plan
- C. Management
    1. Staff Training

2. Systems Engineering/Project Management
3. Environmental Conferences
4. Update Environmental Requirements/817 Business Plan

D. Other
1. Prototype Manufacture
2. System Test & Evaluation

II. Procurement

A. Compliance, Plans, Permits, Reports, Tests & Assessments
1. NEPA (ESH)
2. Site Surveys

B. Pollution Prevention/Waste Management

C. Management
1. Systems Engineering/Project Management
2. Environmental Conferences
3. Update Environmental Requirements/817 Business Plan

D. Other
1. All Prime and Sub-Contractor environmental overhead costs.
   Examples:
   a. Aircraft Manufacturing
   b. Initial Spares & Consumables
   c. Prime Vendor Initial Depot Level Reparables (DLRs)
   d. Initial Support Equipment
   e. Tests and Evaluations
   f. Ammunition Manufacture
   g. Computer Hardware, Semiconductor Manufacturing

III. Operation & Support

A. Compliance, Plans, Permits, Reports, Tests & Assessments
1. NEPA (ESH)
2. Air Emissions Baseline

B. Pollution Prevention/Waste Management
1. End Item Maintenance
2. Repair of DLRs
3. Attrited Aircraft Disposal
4. Aircraft Wash Wastes
5. Depainting/Repainting
   a. Grey water disposal
   b. Blast media disposal
   c. Paint chip removal
   d. Ventilation/Air control
6. Disposal of Line Replaceable Unit (LRU) Consumables

C. Remediation and Restoration of Aircraft Crash Sites

D. Management
1. Environmental Conferences
2. Update Environmental Requirements/817 Business Plan

E. Contractor Environmental Expense
    1. Replenishment Consumables
    2. Replenishment DLRs
    3. System Test & Evaluation (11, 1.6:1.7) (12, 1.6:1.7)

Determining the ELCC estimates of both programs also allowed the Army to improve the visibility of the environmental impacts and costs, identify opportunities to reduce environmental costs, and save money by reducing the overall total life cycle cost. This ELCC estimating methodology also helped the Army improve their overall ESH acquisition policies, evaluate and document environmental considerations, and integrate ESH more efficiently into the acquisition process. (11, 1.3:1.5) (12, 1.3:1.5)

4.2.3.3.4 NDCEE ECAM. The National Defense Center of Environmental Excellence (NDCEE) developed the Environmental Cost Analysis Methodology (ECAM) to evaluate environmental costs and technologies that address compliance and pollution prevention issues for the Environmental Security Technology Certification Program (ESTCP). This methodology is specifically described in Section 2.6.3.2.3. ECAM has been applied at five DoD installations that fielded or evaluated different technologies that where designed to eliminate or reduce potentially adverse environmental impacts and reduce costs. The installations and technologies are listed below and summarized in Table 4-3:

1. Corpus Christi Army Depot in Corpus Christi, Texas (CCAD) installed an ultrahigh-pressure waterjet system to strip metal coatings from aircraft parts and eliminated the chemical stripping process.

2. Tobyhanna Army Depot in Tobyhanna, Pennsylvania (TYAD) added a diffusion dialysis system to a plating process that recovered and recycled spent acid classified as hazardous waste.
3. Watervliet Arsenal in Watervliet, New York (WVA) added a waste acid detoxification and reclamation system to a plating process to recover and recycle spent acid classified as hazardous waste.
4. Navy Aviation Depot in Jacksonville, Florida (NAVDEP-JAX) now use a high-velocity oxygen-fuel thermal spray coatings to repair and maintain aircraft components instead of a chromium plating processes.
5. Warner Robins Air Logistics Center in Georgia (WR-ALC) eliminated high-volatile organic (VOC) compound conformal coatings from their circuit card process. (17, iii)

Table 4-4 compares traditional cost estimating methodologies to ECAM. Payback is the amount of time needed to break even after investing in the new environmental technology. Net Present Value (NPV) is amount of money the new environmental technology will save the government. The Savings category is the difference in NPV identified by the traditional accounting and ECAM approaches. Percent environmental (% Env) is the percentage of environmental costs compared to the overall total operating costs. In most cases, the analyst identified a better payback period, larger NPV, and more savings for the new environmental technology by using ECAM. ECAM also identified the old technology process had a larger environmental cost burden compared to the total operating costs than previously calculated. The reason for the differences between the traditional accounting methods and ECAM is that ECAM

analyzes both direct and indirect environmental costs associated with the old and new technologies.

Table 4-3. ECAM Applications (17, iii)

Site	Process	Old Technology	New Technology
CCAD	Remove coatings from aircraft parts	Use a chemical dip process and dispose of chemicals as a hazardous waste	Use an automated ultrahigh pressure waterjet to remove and collect coating and then dispose of as non-hazardous solid waste
TYAD	Plate small metal parts using acid dip process	Dispose of used acids as hazardous waste	Recover / recycle used acid with a diffusion dialysis system
WVA	Plate large metal parts using an acid dip process	Used acid is disposed as a hazardous waste	Used acid is recycled / recovered with a waste acid detoxification and reclamation system
NADEP-JAX	Refurbish / plate aircraft components	Plate parts using an electrolytic hard (hexavalent) chrome process	Plate parts using a high velocity process (uses tungsten carbide contact powder instead of hexavalent chrome)
WR-ALC	Circuit card assembly and repair	Remove high-VOC conformal coatings and surface applications and replace coating	Use low-VOC conformal coatings or leave circuit cards uncoated

4.2.3.4 Military Case Study Summary. The four military case studies show that the ELCC can be calculated for a DoD weapon system program. Most programs do not calculate their ELCC because the short and long-range plans detailed in the DoD Evaluation have not been implemented. Weapon system programs need a set of standardized environmental cost categories and an accepted ELCC methodology or model to help calculate its ELCC. Weapon system programs do not want to expend

limited resources to calculate its ELCC especially when there are so many variations and uncertainties with ELCC methodologies and models. These case studies demonstrate that there is more than one way to calculate the ELCC of a weapon system and different degrees of accuracy with each methodology that can lead to confusion or inaccuracy. It also shows that it is difficult to compare the results of these methodologies because the costs are developed, organized, and calculated differently. The only way to compare the performance of these programs is if they calculated their ELCC using the same procedures and standardized environmental cost categories.

Table 4-4. ECAM Results (17, v)

Economic Indicator -->		Payback	NPV	Savings	% Env
Site	**Method**	**(yr.)**	**($k)**	**(%)**	**(%)**
CCAD	Trad	4.8	0.0174	23	15
	ECAM	1.3	658	78	26
TYAD	Trad	1.5	72	71	7
	ECAM	0.9	191	114	21
WVA	Trad	7.6	685	15	29
	ECAM	7.0	753	16	19
NADEP-JAX	Trad	N/A	(4,300)	N/A	15
	ECAM	0.2	9,800	444	37
WR-ALC	Trad	N/A	N/A	N/A	N/A
	ECAM	none	none	N/A	1

4.2.4 Reasons for Implementing an DoD ELCC Methodology or Model.

There are three major reasons why an ELCC methodology or model should be implemented for DoD weapon system programs. First, it is the intent of Congress for all DoD organizations to track the ELCC for all MDAPs. Second, several governmental

officials feel that calculating the ELCC for DoD MDAPs is beneficial and are trying to implement policy that will require this to happen. Third, both civilian and military organizations have demonstrated that implementing an ELCC methodology or model has improved their organizations and allowed them to gain a better grasp of their environmental program. None of these organizations documented any major problems or regrets for time and money required for implementing their ELCC methodology or model. Developing an ELCC methodology or model for DoD weapon system programs will provide a systematic method for evaluating the ELCC of a program and evaluate alternatives that can have substantial benefit and cost savings for the life of the program and DoD in general.

4.3 Determination of Standardized Environmental Cost Categories

This section will evaluate what other organizations use for environmental cost categories according to the standards set in Section 3.3.1 and then develop a standardized set of environmental cost categories for DoD using a benchmarking approach explained in Section 3.3. The first part of this section will evaluate the environmental cost categories the Army used for their Comanche and Apache Helicopter Programs. The second part of this section will evaluate what the Joint Strike Fighter (JSF) uses for their environmental cost categories. The third part of this section will evaluate the environmental cost categories developed in the DoD report discussed in Sections 2.6.3.2 and 4.2.3.3.1. In the fourth part of this section, all three sets of these environmental cost categories will be compared against each other and evaluated for strong and weak areas.

Finally, a standardized set of environmental cost categories will be proposed for DoD by using a benchmarking approach.

4.3.1 Army Environmental Cost Categories.

4.3.1.1 Environmental Cost Categories. The U. S. Army Cost and Economic Analysis Center (USACEAC) and USAEC developed an environmental WBS to determine the ELCC of a weapon system. This environmental WBS is documented and defined in Chapter 6 of the USACEAC Cost Analysis Manual (CAM). This WBS has been used to calculate an ELCC estimate for both Comanche and Apache Helicopter Programs.

The Army Environmental WBS is broken down into eight major categories. The major categories are Compliance, Plans, Permits, Tests, and Assessments; Pollution Prevention and Waste Minimization; Natural and Cultural Resource Preservation; Demilitarization and Disposal; Management; Cost and Liability Risk; and Contractor Environmental Costs. Each major category will be defined in the following paragraphs and then the entire environmental WBS will be listed. Note: only the categories and subcategories will be discussed in this document because each weapon system divides their subcategories differently. Examples of these divided subcategories are included in the entire environmental WBS. (10, 86-107) (11, 2.3) (12, 2.3)

The Compliance, Plans, Permits, Tests, and Assessments Category includes costs associated with attaining and sustaining compliance with international, federal, state, and local environmental laws and regulations. This category is broken down into several subcategories related with the different environmental media (e.g. air emissions,

hazardous materials, hazardous waste, noise, etc.). Some of the typical costs in this category include NEPA studies, permits fees, and toxicology testing. (11, 2.3) (12, 2.3)

The Pollution Prevention and Waste Management Category includes costs associated with the development and implementation of pollution prevention and waste minimization programs. This category also includes the control, operation, and disposal of hazardous materials and wastes throughout each phase of the acquisition life cycle. This category is also broken down into subcategories related with the different environmental media. (11, 2.3) (12, 2.3)

The Natural and Cultural Resource Preservation Category includes costs associated with natural and cultural preservation for use by current and future generations. Some examples of these costs include protecting and preserving wetlands, historical areas, Native American burial grounds, and threatened or endangered species of plants and animals. (11, 2.4) (12, 2.4)

The Remediation and Restoration Category includes costs associated with the environmental cleanup of accident or crash sites. This cost is only associated with peacetime operations (e.g. training). This category is broken down into subcategories related to Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA) investigation, study, site assessment, design, and cleanup activities. (11, 2.4) (12, 2.4)

The Demilitarization and Disposal Category includes the cost of disposing of a system or facility at the end of its useful life. This category is broken into two subcategories: Facilities and Systems. Some costs associated with this category are

decontamination, asbestos removal, interim storage, disassembly, and disposal. (11, 2.4) (12, 2.4)

The Management Category includes costs associated with the management of environmental programs. This category is subdivided into four subcategories: Management and Technical Support, Training, Health and Safety Support, and Public Relations. Some costs associated with this category are Request for Proposal (RFP) preparation, training courses, source selection support, In Process Reviews (IPR), and travel. (11, 2.4-2.5) (12, 2.4-2.5)

The Cost and Liability Risk Category includes costs associated with liability and risk and is broken down into subcategories related with the different environmental media. Some costs associated with category are legal claims resulting from adverse environmental impacts caused by the operation of the weapon system. Some examples of these legal claims are costs of property devaluation and personal health issues resulting from contamination of public or private property. (11, 2.5) (12, 2.5)

The Contractor Environmental Costs Category includes environmental costs incurred by a contractor associated with the weapon system. These environmental costs are usually not specifically detailed by the contractor, but are incorporated into their overhead costs. (11, 2.5) (12, 2.5)

The following list contains the entire Army Environmental WBS used for the estimation of the Apache and Comanche Helicopter Program ELCC:

- 1.1 Compliance Plans, Permits, Reports, Tests & Assessments
  - 1.1.1 Air Emissions (Example Detail)
    - 1.1.1.1 Plans, Reports, and Permits
    - 1.1.1.2 Tests, Audits, and Assessments
  - 1.1.2 Hazardous Materials

1.1.3 Hazardous & Radioactive Waste
1.1.4 Noise
1.1.5 Pesticides
1.1.6 Petroleum, Oils, & Lubricants
1.1.7 Solid Waste
1.1.8 Water & Wastewater
1.1.9 Special Programs
1.2 Pollution Prevention/Waste Minimization
1.2.1 Air Emissions
1.2.1.1 Fuel Burners
1.2.1.2 Incinerators
1.2.1.3 Volatile Organic Chemicals
1.2.1.4 Vehicles and Mobile Sources
1.2.1.5 Ozone-Depleting Chemicals
1.2.1.6 Particulates & Metals
1.2.1.7 Air Toxins, Metals
1.2.1.8 Area Sources
1.2.2 Hazardous Materials Handling
1.2.2.1 Storage Structures
1.2.2.2 Operations & Handling
1.2.3 Hazardous Solid & Radioactive Waste
1.2.3.1 Accumulation & Interim Storage
1.2.3.2 Pre-Treatment, Material Separations & Recycling
1.2.3.3 Treatment, Storage, and Disposal
1.2.4 Noise Reduction Processes
1.2.5 Pesticides/Herbicides
1.2.6 Petroleum, Oils & Lubricants
1.2.6.1 Above-Ground Tanks
1.2.6.2 Underground Tanks
1.2.6.3 Drum Storage
1.2.6.4 Waste Treatment
1.2.6.5 Separations & Recycling
1.2.7 Non-Hazardous Solid Waste
1.2.7.1 Material Separations & Recycling
1.2.7.2 Landfills & Receptacles
1.2.7.3 Medical Waste & Special Programs
1.2.8 Water Quality & Wastewater Treatment
1.2.8.1 Water Supply & Distribution System
1.2.8.2 Domestic Wastewater Treatment & Reclamation
1.2.8.3 Industrial Wastewater & Treatment
1.2.8.4 Storm water Runoff Collection & Treatment
1.2.9 Special Programs
1.2.9.1 PCBs
1.2.9.2 Asbestos
1.2.9.3 Radon

- 1.2.9.4 Lead-based Paint
- 1.2.9.5 Low-level Radiation
- 1.2.9.6 Explosives/Energetics

1.3 Natural/Cultural Resource Preservation
- 1.3.1 Biological & Recreational Resources
- 1.3.2 Cultural/Historic Resources
- 1.3.3 Wetlands/Floodplains
- 1.3.4 Land Use

1.4 Remediation & Restoration
- 1.4.1 RI/FS & Site Assessments
- 1.4.2 Restoration Design
- 1.4.3 Remediation Processes
  - 1.4.3.1 Ground Water
  - 1.4.3.2 Surface Water
  - 1.4.3.3 In-Situ Soil
  - 1.4.3.4 Ex-Situ Soil/Solids

1.5 Demilitarization & Disposal
- 1.5.1 Facilities
  - 1.5.1.1 Facility Deactivation/ Equipment Dismantlement & Caretaker Activities
  - 1.5.1.2 Facility Decontamination
    - 1.5.1.2.1 Surface Removal of Particulate Materials
    - 1.5.1.2.2 Surface Removal of Organic / Metal Oxide Chemicals
    - 1.5.1.2.3 Surface Removal of Radioactive Materials
    - 1.5.1.2.4 Asbestos Abatement
  - 1.5.1.3 Facility Demolition
- 1.5.2 Equipment/Systems/Materials
  - 1.5.2.1 Demilitarization & Disposal Process Equip/Facility Design and Construction
  - 1.5.2.2 Interim Storage
  - 1.5.2.3 Disassembly, Disposition, and Disposal

1.6 Management
- 1.6.1 Management & Technical Support
- 1.6.2 Training
- 1.6.3 Health & Safety Support
- 1.6.4 Public Relations

1.7 Cost & Liability Risk
- 1.7.1 Air Emissions
- 1.7.2 Hazardous Materials
- 1.7.3 Hazardous & Radioactive Waste
- 1.7.4 Noise
- 1.7.5 Pesticides
- 1.7.6 Petroleum, Oils, & Lubricants
- 1.7.7 Solid Waste

1.7.8 Water & Wastewater
1.7.9 Unknowns
1.8 Contractor Environmental Costs (10, 86-107)

4.3.1.2 Evaluation of Environmental Cost Categories.

4.3.1.2.1 Inclusiveness. The Army Environmental WBS provides a good overall hierarchy to evaluate environmental costs. It includes the major types of pollution (air, water, noise, etc.) and pollutants (hazardous materials and waste, pesticides, petroleum, etc.). It also breaks the major categories into specific subcategories that will provide useful information to help reduce or eliminate environmental costs. This WBS also includes special categories for liability, natural and cultural resources, and different management costs.

4.3.1.2.2 Compatibility. This WBS is complex and requires careful attention to ensure that environmental costs are accounted for in the proper DoD appropriation or acquisition phase and not duplicated. Each category must also be subdivided into each DoD appropriation and acquisition phase to ensure these figures are properly calculated. This can be cumbersome and might make it difficult for an analyst to input data and interpret results.

4.3.1.2.3 Categories. This WBS will provide managers at all levels information they can use to evaluate environmental life cycle costs. It will clearly point out what areas are most significant and need attention. It can also be used to develop short and long-term strategies to help reduce the overall impact and cost. One problem with this environment WBS is that production and operation costs are mixed in with several other environmental costs. Better clarity and insight might be gained if these costs were documented separately.

4.3.2 Joint Strike Fighter Environmental Cost Categories.

4.3.2.1 Environmental Cost Categories. The Joint Strike Fighter (JSF) Support Office ESH Section developed an environmental WBS to account for their environmental costs. This environmental WBS is documented in a draft copy of the ESH section of the JSF Cost Analysis Requirements Description (CARD). This WBS is not completely developed because the JSF is only in the Program Definition and Risk Reduction (PDRR) Phase.

The JSF Environmental WBS is broken down into five major categories. The major categories are Compliance Plans, Permits, Tests, and Assessments; Pollution Prevention and Waste Management; Production; Operations / Maintenance / Deployment, and Disposal and Demilitarization. Each major category will be defined in the following paragraphs and then the entire environmental WBS will be listed. (8)

The Compliance, Plans, Permits, Tests, and Assessments Category includes all costs associated with attaining and sustaining compliance with international, federal, state, and local environmental laws and regulations. This category is broken down into several subcategories related with the different environmental media (e.g. air emissions, hazardous materials, hazardous waste, noise, etc.). Some of the typical costs in this category include administrative support, NEPA studies, permits fees, and toxicology testing. (8)

The Pollution Prevention and Waste Management Category includes the costs associated with the development and implementation of pollution prevention and waste minimization programs. This category is also broken down into subcategories related with the different environmental media. (8)

The Production Category includes the costs associated with the control, operation, and disposal of hazardous materials and wastes throughout the production phase of the acquisition life cycle. This category also includes costs associated with occupational health and safety, air management, process-related labor, and utilities. (8)

The Operations / Maintenance / Deployment Category includes the costs associated with the control, operation, and disposal of hazardous materials and wastes throughout the operation and support phase of the acquisition life cycle. This category also includes costs associated with occupational health and safety, air management, process-related labor, and utilities. (8)

The Demilitarization and Disposal Category includes the cost of disposing of the weapon system and support systems at the end of their useful life. This category is broken into several subcategories: storage, disassembly, component disposition, hazardous material management and disposal, reclamation / reuse, support equipment disposal, and trainer disposal. Some costs associated with this category are decontamination, interim storage, disassembly, and disposal. (8)

The following list contains the entire JSF Environmental WBS used for the estimation of their ELCC:

- 1.1 Compliance, Plans, Permits, Reports
  - 1.1.1 Air Emissions
  - 1.1.2 Hazardous Materials
  - 1.1.3 Solid Hazardous Waste
  - 1.1.4 Noise
  - 1.1.5 Petroleum, Oils, Lubricants
  - 1.1.6 Solid Waste (Non-Hazardous)
  - 1.1.7 Water/Waste Water
- 1.2 Pollution Prevention/Waste Management
  - 1.2.1 Air Emissions Control
  - 1.2.2 Hazardous Material Management

- 1.2.3 Regulated Solid Waste Disposal
- 1.2.4 Noise Reduction Processes
- 1.2.5 Petroleum, Oils, Lubricants
- 1.2.6 Solid Waste (Non-Hazardous)
- 1.2.7 Pollution Prevention Technology Procurement

1.3 Production
- 1.3.1 Hazardous Material Procurement
- 1.3.2 Hazardous Material Management
- 1.3.3 Regulated Waste Disposal
- 1.3.4 Hazardous Waste Management
- 1.3.5 Air Management
- 1.3.6 Occupational Health and Safety (Administrative)
- 1.3.7 Occupational Health and Safety (Personal Protective Equipment, etc.)
- 1.3.8 Process Related Labor
- 1.3.9 Utilities

1.4 Operations/Maintenance/Deployment
- 1.4.1 Hazardous Material Procurement
- 1.4.2 Hazardous Material Management
- 1.4.3 Regulated Waste Disposal
- 1.4.4 Hazardous Waste Management
- 1.4.5 Air Management
- 1.4.6 Occupational Health and Safety (Administrative)
- 1.4.7 Occupational Health and Safety (Personal Protective Equipment, etc.)
- 1.4.8 Process Related Labor
- 1.4.9 Utilities

1.5 Disposal and Demilitarization
- 1.5.1 Storage
- 1.5.2 Disassembly
- 1.5.3 Component Disposition
- 1.5.4 Hazardous Material Management and Disposal
- 1.5.6 Reclamation/Reuse
- 1.5.7 Peculiar Support Equipment Disposal
- 1.5.8 Trainer Disposal (8)

4.3.2.2 Evaluation of Environmental Cost Categories.

4.3.2.2.1 Inclusiveness. This environmental WBS is not as complex or specific as the Army Environmental WBS. However, it does provide a basic overview of the major environmental costs associated with a program. It is missing (or does not specifically break out) some categories that are sometimes difficult to account. These

cost categories include management and personnel, facilities, natural and cultural resources, remediation and restoration, and cost and risk liability.

4.3.2.2.2 Compatibility. The JSF environmental cost categories mesh with the DoD acquisition life cycle phases and largest appropriation categories. The most expensive categories, Production And Operation / Maintenance / Deployment, are separated and allow an analyst to specifically account for these environmental costs. One problem with this environmental WBS is that MILCON or MILPERS appropriations are not clearly separated.

4.3.2.2.3 Categories. This WBS will provide managers at all levels information they can use to evaluate environmental life cycle costs. It will clearly point out what areas are most significant and need attention. It can also be used to develop short and long-term strategies to help reduce the overall impact and cost. It should be noted that the subcategories need additional breakdowns to provide managers with a clearer picture on which specific materials or processes need improvement.

4.3.3 DoD Evaluation Cost Categories.

4.3.3.1 Environmental Cost Categories. The Capstone Corporation developed an environmental WBS for the Office of the Director of Program Analysis and Evaluation to determine the ELCC of a weapon system. This environmental WBS is documented and defined the report "Environmental Management Category Report for the Survey of Resources Available for estimating the Environmental Costs of Major Defense Acquisition Programs." This environmental WBS was developed to evaluate several different ELCC methodologies and models. (18, 1)

The DoD Evaluation WBS is broken down into five major categories. The major categories are Environmental Program Management; HTR Material Management; HTR Waste Management; Environmental Restoration / Corrective Measures; and HTR Material and Waste Transportation. Each major category will be defined in the following paragraphs and then the entire environmental WBS will be listed. (18, 3)

The Environmental Program Management Category includes costs associated with the development of plans and programs associated with pollution prevention, compliance, and conservation. This category also includes the professional support associated with these plans and programs, plus other environmental management activities. This category is divided into two subcategories: Program Management and Program Support. (18, 7-9)

The HTR Material Management Category includes the costs associated with the management and control of hazardous materials. This category also includes pollution prevention and compliance implementation and the construction or acquisition of facilities or equipment associated with HTR materials. This category is divided into three subcategories: HTR Material Management and Support, HTR Material Control and Distribution, and HTR Material Management Facilities. (18, 10-13)

The HTR Waste Management Category includes the costs associated with the management, control, treatment, storage, and disposal of hazardous wastes. This category also includes pollution prevention and compliance implementation and the construction or acquisition of facilities or equipment associated with HTR materials. This category is divided into three subcategories: HTR Waste Operations Management

and Support, On-site Waste Management Facility Construction / Operations, and off-site HTR Waste Disposal. (18, 14-17)

The Environmental Restoration / Corrective Measure Category includes costs associated with the environmental cleanup required to restore polluted areas to acceptable levels. This category is broken down into subcategories related to CERCLA and RCRA investigation, study, site assessment, design, and cleanup activities. (18, 18-22)

The HTR Material and Waste Transportation Category includes costs associated with activities to manifest, permit, load, transport, and unload HTR materials and wastes throughout the life cycle of the weapon system. This category is divided into two subcategories: Transportation Management and Transportation. (18, 23)

The following list contains the entire DoD Evaluation Environmental WBS used for the evaluation of several ELCC methodologies and models:

- 1.0 Environmental Program Management
  - 1.01 Program Management
    - 1.01.01 Program Planning
    - 1.01.02 Compliance Management
    - 1.01.03 Pollution Prevention Management
    - 1.01.04 Conservation Management
    - 1.01.05 Other
  - 1.02 Program Support
    - 1.02.01 Training / Certification
    - 1.02.02 Public Affairs
    - 1.02.03 Engineering and Administrative Support
    - 1.02.04 Legal Support
    - 1.02.05 Medical Support
    - 1.02.06 Health and Safety
    - 1.02.07 Quality Assurance / Quality Control
    - 1.02.08 Emergency Response
    - 1.02.09 Other
- 2.0 HTR Material Management
  - 2.01 HTR Material Management and Support
    - 2.01.01 Pollution Prevention Program Implementation
    - 2.01.02 Compliance Program Implementation

- 2.01.03 Other
- 2.02 HTR Material Control and Distribution
  - 2.02.01 Requisition / Acquisition
  - 2.02.02 Handling / Distribution
  - 2.02.03 Management / Control of Use
  - 2.02.04 Recovery
  - 2.02.05 Reuse
  - 2.02.06 Recycle
  - 2.02.07 Other
- 2.03 HTR Material Management Facilities
  - 2.03.01 Personal Protection
  - 2.03.02 HTR Capital Facilities / Equipment
  - 2.03.03 Other
- 3.0 HTR Waste Management
  - 3.01 HTR Waste Operations Management and Support
    - 3.01.01 Pollution Prevention Program Implementation
    - 3.01.02 Compliance Program Implementation
    - 3.01.03 Other
  - 3.02 On-site Waste Management Facility Construction / Operations
    - 3.02.01 Treatment Facility Construction / Operations
    - 3.02.02 Treatment Facility Decontamination and Decommissioning
    - 3.02.03 Storage Facility Construction / Operations
    - 3.02.04 Storage Facility Decontamination and Decommissioning
    - 3.02.05 Disposal Facility Construction / Operations
    - 3.02.06 Treatment, Storage, and Disposal Facility Closure
    - 3.02.07 Other
  - 3.03 Off-site HTR Waste Disposal
    - 3.03.01 Commercial Fees
    - 3.03.02 Other than Commercial Fees
- 4.0 Environmental Restoration / Corrective Measures
  - 4.01 Preliminary Assessment Site Investigation (PA/SI) and/or RCRA Facility Assessment (RFA)
  - 4.02 Remedial Investigation / Feasibility Study (RI/FS) and/or RCRA Facility Investigation / Corrective Measures Study (RFI/CMS)
  - 4.03 Remedial Design
  - 4.04 Remedial Action and/or Corrective Measures
- 5.0 HTR Material and Waste Transportation
  - 5.01 Transportation Management
  - 5.02 Transportation (18, 7-23)

4.3.3.2 Evaluation of Environmental Cost Categories.

4.3.3.2.1 Inclusiveness. The DoD Evaluation Environmental WBS incorporates most environmental costs associated with a weapon system program. This environmental WBS provides a basic overview of the major environmental costs associated with a program. It is missing (or does not specifically break out) four categories that are sometimes difficult to account. These cost categories include production, operation, natural and cultural resources, and cost and risk liability.

4.3.3.2.2 Compatibility. The DoD Evaluation Environmental WBS does not mesh with the DoD acquisition life cycle phases and largest appropriation categories. The most expensive categories, Production And Operation / Maintenance / Deployment, are not separated for an analyst who specifically needs to account for these environmental costs. Another problem with this environmental WBS is that MILCON or MILPERS appropriations are not clearly separated.

4.3.3.2.3 Categories. This environmental WBS will only provide managers basic information to evaluate the ELCC of their program. It can provide information to help develop short and long-term strategies to help reduce the overall impact and cost. This environmental WBS can show which hazardous materials and wastes are the significant cost drivers, but it does not necessarily specify what phase this situation is occurring. The major problem with this environment WBS is that production and operation costs are mixed in with several other environmental costs. Better clarity and insight might be gained if these costs were documented separately.

4.3.4 Comparison of Environmental Cost Categories. It is difficult to compare three distinct environmental WBS because they can define cost categories differently.

The three sets of environmental cost categories were organized into nine different environmental cost groups to organize them collectively. The nine different environmental cost groups are management, pollution prevention, production, operations and support, disposal, cleanup, facilities, risk, and other. The environmental cost groups were developed from the major activities and costs associated throughout the life cycle of a weapon system detailed in Chapter 2. Table 4-5 shows how the three sets of environmental cost categories fit into the eight different groups.

Each set of environmental cost categories had one to two categories in management, pollution prevention, production, operations and support, and disposal groups. Two sets of environmental cost categories had at least one category in the cleanup, facilities, and other groups. Only one set of environment cost categories had one category in the risk group.

Table 4-5 also shows how different environmental cost categories can be in several environmental cost groups. This is caused by organizations oversimplifying or not defining their environmental cost categories specifically. Table 4-5 depicts the major problem of not having standardized environmental cost categories – three organizations have three distinct sets of environmental cost categories that calculate different cost figures. The environmental cost groups from Table 4-5 will be used to develop a standardized set of environmental cost categories in the next section.

Table 4-5. Comparison of Environmental Cost Categories

Categories	AEC	JSF	DoD
Management	• Management • Plans, Permits, Reports, Tests, and Assessments	• Compliance Plans, Permits, Reports	• Environmental Program Management
Pollution Prevention	• Pollution Prevention / Waste Minimization	• Pollution Prevention / Waste Management	• HTR Management and Support • HTR Waste Operations Management and Support
Production	• Contractor Environmental Costs	• Production	• HTR Material Control and Distribution
Operations and Support	• Pollution Prevention / Waste Minimization • Contractor Environmental Costs	• Operations / Maintenance / Deployment	• HTR Material Control and Distribution • On-site Waste Facility Construction / Operations
Disposal	• Demilitarization and Disposal	• Disposal and Demilitarization	• Off-site HTR Waste Disposal
Cleanup	• Remediation and Restoration		• Environmental Restoration / Correction Measures
Facilities	• Pollution Prevention / Waste Minimization • Demilitarization and Disposal		• HTR Management and Support • HTR Waste Operations Management and Support
Risk	• Cost and Liability Risk		
Other	• Natural / Cultural Resource Preservation		• HTR Material and Waste Transportation

4.3.5 Determination of Environmental Cost Categories. To evaluate the ELCC of a DoD major weapon system, environmental costs must be defined. This section will recommend a way to define environmental costs associated with DoD major weapon systems. It will use the analysis from Section 4.3.4 to determine how environmental cost categories should be organized for a DoD weapon system. This section will also format the environmental costs into a WBS format that takes into account different DoD appropriations or acquisition phases to follow the current DoD costing techniques.

To ensure the Inclusiveness Criterion is met, Table 4-6 shows the major environmental cost categories throughout the life cycle of a weapon system by using the

environmental cost groups from Table 4-5. The environmental cost categories for each acquisition life cycle phase in Table 4-6 were determined by analyzing typical environmental activities at different MDAP (Apache, Comanche, and JSF), evaluating the Potential Mapping of ESH Costs to Acquisition Phase WBS Elements Table from the AFESHCAG (see Appendix K), and comparing them to the environmental cost groups from Table 4-5. To ensure the Compatibility Criterion is met, the environmental cost categories from Table 4-6 are incorporated into the following WBS format. The environmental cost categories are organized in a manner that takes into account the best aspects of the Army, JSF, and DoD Evaluation WBS formats. These environmental cost categories should provide managers with usable structure in the form of a WBS to evaluate their environmental program.

- 1.0 Management
    - 1.01 Program Management
        - 1.01.01 Program Planning
        - 1.01.02 Compliance Management
        - 1.01.03 Pollution Prevention Management
        - 1.01.04 Conservation Management
        - 1.01.05 Other
    - 1.02 Program Support
        - 1.02.01 Training / Certification
        - 1.02.02 Public Affairs
        - 1.02.03 Engineering and Administrative Support
        - 1.02.04 Legal Support
        - 1.02.05 Medical Support
        - 1.02.06 Health and Safety
        - 1.02.07 Quality Assurance / Quality Control
        - 1.02.08 Emergency Response
        - 1.02.09 Other
- 2.0 Plans, Permits, Reports, Tests, and Assessments
    - 2.01 Air Emissions
    - 2.02 Hazardous Materials
    - 2.03 Hazardous & Radioactive Waste
    - 2.04 Noise
    - 2.05 Pesticides

- 2.06 Petroleum, Oils, & Lubricants
- 2.07 Solid Waste
- 2.08 Water & Wastewater
- 2.09 Special Programs

3.0 Pollution Prevention / Waste Minimization
- 3.01 Air Emissions
- 3.02 Hazardous Materials Handling
- 3.03 Hazardous Solid & Radioactive Waste
- 3.04 Noise Reduction Processes
- 3.05 Pesticides/Herbicides
- 3.06 Petroleum, Oils & Lubricants
- 3.07 Non-Hazardous Solid Waste
- 3.08 Water Quality & Wastewater Treatment
- 3.09 Special Programs

4.0 Production
- 4.01 Hazardous Material Procurement
- 4.02 Hazardous Material Management
- 4.03 Regulated Waste Disposal
- 4.04 Hazardous Waste Management
- 4.05 Air Management
- 4.06 Occupational Health and Safety (Administrative)
- 4.07 Occupational Health and Safety (Personal Protective Equipment, etc.)
- 4.08 Process Related Labor
- 4.09 Utilities

5.0 Operations / Maintenance / Deployment
- 5.01 Hazardous Material Procurement
- 5.02 Hazardous Material Management
- 5.03 Regulated Waste Disposal
- 5.04 Hazardous Waste Management
- 5.05 Air Management
- 5.06 Occupational Health and Safety (Administrative)
- 5.07 Occupational Health and Safety (Personal Protective Equipment, etc.)
- 5.08 Process Related Labor
- 5.09 Utilities

6.0 Demilitarization and Disposal
- 6.01 Storage
- 6.02 Disassembly
- 6.03 Component Disposition
- 6.04 Hazardous Material Management and Disposal
- 6.05 Reclamation/Reuse
- 6.06 Peculiar Support Equipment Disposal
- 6.07 Trainer Disposal

7.0 Remediation and Restoration
- 7.01 Preliminary Assessment Site Investigation (PA/SI) and/or RCRA Facility Assessment (RFA)

7.02 Remedial Investigation / Feasibility Study (RI/FS) and/or RCRA Facility Investigation / Corrective Measures Study (RFI/CMS)
7.03 Remedial Design
7.04 Remedial Action and/or Corrective Measures

8.0 Facilities
8.01 Environmental Projects for New or Existing Facilities
8.02 Facility Deactivation / Equipment Dismantlement & Caretaker Activities
8.03 Facility Decontamination
8.04 Facility Demolition

9.0 Natural / Cultural Preservation
9.01 Biological & Recreational Resources
9.02 Cultural/Historic Resources
9.03 Wetlands/Floodplains
9.04 Land Use

10.0 Cost and Liability Risk
10.01 Air Emissions
10.02 Hazardous Materials
10.03 Hazardous & Radioactive Waste
10.04 Noise
10.05 Pesticides
10.06 Petroleum, Oils, & Lubricants
10.07 Solid Waste
10.08 Water & Wastewater
10.09 Unknowns

To ensure the Category Criterion is met, the environmental cost categories from Table 4-6 are defined in the following paragraphs. The following environmental cost category definitions are derived from the different environmental cost category definitions presented in Sections 4.3.1, 4.3.2, and 4.3.3.

The Management Category includes costs associated with the development of plans and programs associated with pollution prevention, compliance, and conservation. This category also includes the professional support associated with these plans and programs, plus other environmental management activities. This category is divided into two subcategories: Program Management and Program Support.

The Plans, Permits, Tests, and Assessments Category includes all costs associated with attaining and sustaining compliance with international, federal, state, and local environmental laws and regulations. This category is broken down into several subcategories related with the different environmental media (e.g. air emissions, hazardous materials, hazardous waste, noise, etc.). Some of the typical costs in this category include administrative support, NEPA studies, permits fees, and toxicology testing.

Table 4-6. Acquisition Life Cycle Environmental Cost Categories

CE	PDRR	EMD	Prod	O&S	D&D
Management	Management	Management	Management	Management	Management
Plans, Permits, Reports, Tests, and Assessments	Plans, Permits, Reports, Tests, and Assessments	Plans, Permits, Reports, Tests, and Assessments	Plans, Permits, Reports, Tests, and Assessments	Plans, Permits, Reports, Tests, and Assessments	Plans, Permits, Reports, Tests, and Assessments
Pollution Prevention / Waste Minimization	Pollution Prevention / Waste Minimization	Pollution Prevention / Waste Minimization	Pollution Prevention / Waste Minimization	Pollution Prevention / Waste Minimization	Pollution Prevention / Waste Minimization
	Production	Production	Production	Production	
	Operations / Maintenance / Deployment	Operations / Maintenance / Deployment	Operations / Maintenance / Deployment	Operations / Maintenance / Deployment	
	Demilitari-zation and Disposal	Demilitari-zation and Disposal	Demilitari-zation and Disposal	Demilitari-zation and Disposal	Demilitari-zation and Disposal
	Remediation and Restoration	Remediation and Restoration	Remediation and Restoration	Remediation and Restoration	Remediation and Restoration
	Facilities	Facilities	Facilities	Facilities	Facilities
	Natural / Cultural Preservation	Natural / Cultural Preservation	Natural / Cultural Preservation	Natural / Cultural Preservation	Natural / Cultural Preservation
	Cost and Liability Risk	Cost and Liability Risk	Cost and Liability Risk	Cost and Liability Risk	Cost and Liability Risk

The Pollution Prevention and Waste Management Category includes the costs associated with the development and implementation of pollution prevention and waste minimization programs. This category is also broken down into subcategories related with the different environmental media.

The Production Category includes the costs associated with the control, operation, and disposal of hazardous materials and wastes throughout the production phase of the acquisition life cycle. This category also includes costs associated with occupational health and safety, air management, process-related labor, and utilities.

The Operations / Maintenance / Deployment Category includes the costs associated with the control, operation, and disposal of hazardous materials and wastes throughout the operation and support phase of the acquisition life cycle. This category also includes costs associated with occupational health and safety, air management, process-related labor, and utilities.

The Demilitarization and Disposal Category includes the cost of disposing of the weapon system and support systems at the end of their useful life. This category is broken into several subcategories: storage, disassembly, component disposition, hazardous material management and disposal, reclamation / reuse, support equipment disposal, and trainer disposal. Some costs associated with this category are decontamination, interim storage, disassembly, and disposal.

The Remediation and Restoration Category includes costs associated with the environmental cleanup of crash sites. This cost is only associated with peacetime operations (e.g. training). This category is broken down into subcategories related to CERCLA and RCRA investigation, study, site assessment, design, and cleanup activities.

The Facilities Category includes costs associated with the construction and disposal of all facilities related to environmental issues. This category is broken into four subcategories: Environmental Projects for New or Existing Facilities, Facility Deactivation, Facility Decontamination, and Facility Demolition.

The Natural and Cultural Resource Preservation Category includes the costs associated with natural and cultural preservation for use by current and future generations. Some examples of these costs include relocating operations away from wetlands, historical areas, Native American burial grounds, and threatened or endangered species of plants and animals.

The Cost and Liability Risk Category includes costs associated with liability and risk. This category is also broken down into subcategories related with the different environmental media. Some costs associated with category are legal claims resulting from adverse environmental impacts caused by the operation of the weapon system. Some examples of these legal claims are costs of property devaluation and personal health issues resulting from contamination of public or private property.

4.4 Evaluation of Existing ELCC Methodologies and Models

This section will evaluate the Army ELCCM, Navy ELCC Model, and NDCEE ECAM. These methodologies will be evaluated with the assessment criteria developed in Section 3.4.2. Please refer to Section 2.6.3.2 for background information on these DoD ELCC methodologies and models.

4.4.1 Army ELCC Methodology.

4.4.1.1 Background Assessment Criteria.

General Profile Information – Any DoD weapon system program can easily adopt this methodology. The Army Environmental Center developed this methodology and it is currently used by the Comanche, Longbow Apache, and Chinook weapon system programs. This methodology was developed within the past two years and is still being used by the above mentioned weapon system programs.

Application – This methodology is an accounting structure that is used to accurately estimate the ELCC of a weapon system program.

Summary of Methodology / Software – Currently, this methodology does not require any special computer software. In the future, the goal of the Army Environmental Center is to adapt the methodology into ACEIT.

Ease of use – Currently no specific training is required other than background knowledge in the acquisition, environmental, and financial career fields. This methodology does require environmental cost data to be generated and collected wherever the weapon system is produced, operated, and maintained. Once the data is collected, the user must document all assumptions, calculations, and limitations to properly develop and complete the ELCC estimate. This process takes approximately six months to a year to complete.

Economy - The development cost is insignificant because AEC already developed the methodology. The procurement cost is also insignificant because no major computer software must be purchased to use the methodology. The implementation, modification,

and operation costs are expensive because of the amount of labor necessary to gather and input environmental cost data to properly complete the ELCC estimate.

Attributes and Limitations – This methodology is an accounting system and not a computer software program. The methodology only provides a means to track environmental costs. The greatest limitation of this methodology is the amount of environmental cost data required. A user must understand where the data comes from and keep up to date with current and future environmental costs. The user must also understand all the processes that take place at production plants, depots, and unit level organizations to provide an accurate ELCC estimate.

4.4.1.2 Completeness Assessment Criteria.

Life Cycle Stages Covered – This methodology evaluates all DoD acquisition life cycle stages.

Types of Costs Considered – This methodology can incorporate any environmental cost. This methodology is extremely flexible and can organize environmental costs into any set of environmental cost categories, DoD appropriations, or WBS format the weapon system program desires.

4.4.1.3 Sensitivity Assessment Criteria.

Sensitivity Analysis – This model does not have the capability to conduct a sensitivity analysis. This must be completed manually.

Generation of Financial Indicators – This model does not have functions to calculate the net present value, internal rate of return, payback period, or benefit/cost ratio is calculated. This information must be calculated manually.

4.4.1.4 Data Assessment Criteria.

Data availability and sources – This methodology requires a lot of environmental cost data. This data must be gathered from several different locations and updated routinely. Some data may be difficult to obtain depending on which organization (i.e. contractor, depot, unit, etc.) must provide the cost data. The accuracy of the data depends on the data source – the user must manually document where data came from and what organizations were responsible for collecting the data.

Method of Cost Estimation – Depending on the availability and source of data, this methodology can use any type of cost estimate. The user must clearly document this information to ensure that the results are properly analyzed.

4.4.1.5 Output Assessment Criteria.

Validity – The user must understand the how the methodology works and how the environmental costs of each process are calculated. If this requirement is met, the output might reasonably represent the real-world environment, provide results that can be used to serve as a valid and logical basis for selecting an alternative or option, and be accepted by higher management.

Documentation – The output of this methodology is easy to understand and evaluate. The results are presented in a way that can be quickly reviewed and understood by other professionals.

4.4.2 Navy ELCC Model.

4.4.2.1 Background Assessment Criteria.

General Profile Information – Any weapon system program can use this model, but it must be specifically adapted for it to be used properly. This model was developed

by the Naval Air Warfare Center – Aircraft Division in Lakehurst, NJ. Currently, this model only has environmental cost data for the following aircraft: FA18, F14, AV8, E2/C2, S3, P3, EA6, H46, AND H53. This model is not yet complete, but will be ready for use in the near future.

Application – This model is used to estimate the following environmental costs: air emissions planning and reporting, air emissions and control, hazardous material management, hazardous material purchase, hazardous waste management, hazardous waste disposal, and industrial wastewater treatment.

Summary of Methodology / Software – This model uses a Microsoft Access format and only requires 2 MB of memory to be installed.

Ease of use – This model is extremely easy to operate and does not require any special training. If one is familiar with a weapon system program's environmental process, it does not take long to use the model to develop an environmental cost estimate. The only problem is gathering and inputting the weapon system program's specific environmental cost data to use the model. This might require a significant amount of time and money.

Economy – The implementation cost is the most expensive cost due to the amount of data the must be gathered and inputted into the model. Weapon system programs that cannot use the Navy aircraft environmental cost database must gather their own production, organizational and intermediate level maintenance, depot level maintenance, and demilitarization and disposal environmental cost data. This data is located at all installations and organizations (i.e., unit, depot, etc.) specifically associated with the

weapon system program. The development, procurement, and operation costs are insignificant.

Attributes and Limitations – This model is user-friendly because the model is easy to operate and make changes. However, it might require some external support from environmental experts in the field. The greatest limitation with this model is the amount of environmental cost data required. A user must understand where the data comes from and keep up to date with current environmental costs. The user must also understand all the processes that take place at production plants, depots, and unit level organizations to provide an accurate ELCC estimate.

4.4.2.2 Completeness Assessment Criteria.

Life Cycle Stages Covered – This model only calculates production, organizational and intermediate level maintenance, depot level maintenance, and demilitarization and disposal costs. This model does not include costs associated with the CE, PDRR, and entire EMD life cycle stages.

Types of Costs Considered – This model only calculates air emissions planning and reporting, air emissions and control, hazardous material management, hazardous material purchase, hazardous waste management, hazardous waste disposal, and industrial wastewater treatment costs. These costs are compatible with the list environmental cost categories developed in Section 4.3.4. This model does not include the following environmental costs: Research and Development, Pollution Prevention, National Environmental Policy Act (NEPA) Studies, cleanup of aircraft accidents, and Program Environmental Safety and Health Evaluations (PESHE). This model does not directly organize environmental costs into the proper DoD appropriation and WBS

format. However, the environmental costs can be easily transformed into this manner manually.

4.4.2.3 Sensitivity Assessment Criteria.

Sensitivity Analysis – This model does not have the capability to conduct a sensitivity analysis. This must be completed manually.

Generation of Financial Indicators – This model does not have functions to calculate the net present value, internal rate of return, payback period, or benefit/cost ratio is calculated. This information must be calculated manually.

4.4.2.4 Data Assessment Criteria.

Data availability and sources – This model requires a lot of environmental cost data. This data must be gathered from several different locations and updated routinely. Some data may be difficult to find depending on which organization (i.e. contractor, depot, unit, etc.) must provide the cost data. The accuracy of the data depends on the data source – the user manual clearly describes the origin of the data and which organization collected the data.

Method of Cost Estimation – The majority of cost estimates generated from this model are parametric. The model depends on location, aircraft model and quantity, weight, surface area, service life, schedule maintenance times, and man-hour rates.

4.4.2.5 Output Assessment Criteria.

Validity – The user must understand how the model works and how it calculates the environmental costs of each process. If this requirement is met, the output might reasonably represent the real-world environment, provide results that can be used to serve

as a valid and logical basis for selecting an alternative or option, and be accepted by higher management.

Documentation – The output of this model is easy to understand and evaluate. The results are presented in a way that can be quickly reviewed and understood by other professionals.

4.4.3 NDCEE ECAM.

4.4.3.1 Background Assessment Criteria.

General Profile Information – Any DoD weapon system program can use this methodology. The methodology was developed by the National Defense Center for Environmental Excellence and currently used by the Environmental Security Technology Certification Program (ESTCP).

Application – This methodology is a capital investment tool that evaluates investments in environmental technologies that address compliance and pollution prevention issues. It does not calculate the entire ELCC of a weapon system program.

Summary of Methodology / Software – This methodology uses a program developed by the EPA, P2/Finance. This program does require Microsoft EXCEL.

Ease of use – This methodology is not difficult to use and does not require any special training. If one is familiar with a weapon system program's environmental process, it does not take long to use the methodology to develop an environmental cost estimate for a specific environmental technology. The only problem is finding, gathering, and inputting the weapon system program's specific environmental cost data to use the model. This might require a significant amount of labor.

Economy - The operation cost is the most expensive cost due to the amount of labor required gathering and inputting data into the software program. The developmental and procurement are insignificant because the computer software was already developed and purchased. The implementation and modification costs are also insignificant due to the simplicity of the methodology.

Attributes and Limitations – This methodology provides a consistent approach to identify relevant costs and evaluates them with a higher degree of accuracy than traditional cost estimating methodologies. ECAM also identifies, quantifies, and assigns environmental costs and benefits to the process responsible for generating them. The major limitation of this methodology is that it is specifically designed to evaluate selected environmental technologies and not designed to evaluate entire systems over all DoD acquisition life cycle stages.

4.4.3.2 Completeness Assessment Criteria.

Life Cycle Stages Covered – This methodology can evaluate a specific environmental technology over all DoD acquisition life cycle stages.

Types of Costs Considered – This methodology can incorporate any environmental cost. These costs are compatible with the listed environmental cost categories developed in Section 4.3.4. This methodology does not directly organize these environmental costs into the appropriate DoD appropriation and WBS format. However, the environmental costs can be easily transformed into this manner manually.

4.4.3.3 Sensitivity Assessment Criteria.

Sensitivity Analysis – This methodology can perform a sensitivity analysis. The P2/Finance program is connected into EXCEL, which allows it to perform a Monte Carlo simulation using Crystal Ball.

Generation of Financial Indicators – This methodology can evaluate net present value, internal rate of return, payback period, and benefit/cost ratio. The P2/Finance program is an EXCEL adaptation, which allows it to perform all these calculations.

4.4.3.4 Data Assessment Criteria.

Data availability and sources – This methodology requires environmental cost data. Some data may be difficult to find or gather depending on which organization (i.e. contractor, depot, unit, etc.) must provide the cost data. The accuracy of the data depends on the data source – the user can manually document where data came from and what organizations were responsible for collecting the data by using standardized forms developed by ECAM.

Method of Cost Estimation – Depending on the availability and source of data, this methodology can use any type of cost estimate. The user must clearly document this information to ensure that the results are properly analyzed.

4.4.3.5 Output Assessment Criteria.

Validity – The user must understand how the methodology works and how the environmental costs of the process were calculated. If this requirement is met, the output might reasonably represent the real-world environment, provide results that can be used to serve as a valid and logical basis for selecting an alternative or option, and be accepted by higher management.

Documentation – The output of this methodology is easy to understand and evaluate. The results are presented in a way that can be quickly reviewed and understood by other professionals.

4.5 Summary

Calculating the ELCC of a DoD weapon system is important and required by Public Law 103-337 (Section 815). Numerous organizations, both military and civilian, have successfully calculated their ELCC to develop new environmental management strategies and evaluate different alternatives. Even with these success, DoD as a whole has not completely accepted an ELCC methodology or model.

This chapter developed the initial framework for DoD to implement an ELCC methodology. It first evaluated existing environmental cost categories used by three DoD organizations and then developed a standardized set of environmental cost categories for DoD. Then it evaluated three different ELCC; the Army ELCC Methodology, Navy ELCC Model, and National Defense Center for Environmental Excellence (NDCEE) Environmental Cost Analysis Methodology (ECAM). Using the standardized environmental cost categories and the ELCC methodology and model evaluations, a new foundation can be developed to implement a standardized DoD ELCC methodology or model in the next chapter.

V. Conclusion

5.1 Introduction

The purpose of this chapter is to provide a summary of the issues associated with environmental life cycle cost (ELCC) methodologies and models for DoD major weapon system programs, develop a new foundation needed to implement a Department of Defense (DoD) ELCC methodology or model, address the shortcomings and limitations of this study, and discuss future areas of research. The summary section will review the current DoD issues, ELCC methodology and model difficulties, DoD ELCC methodology or model importance, and DoD ELCC methodologies and models. The new foundation section will provide policy suggestions to the Deputy Undersecretary of Defense for Environmental Security (DUSD(ES)) and implementation guidance to the weapon system programs. Difficulties that could not be overcome with this thesis effort are pointed out in the shortcomings and limitations section. Several potential research efforts are documented in the future areas for research section.

The following six research questions were developed in Chapter 1:

1. *What are common difficulties associated with ELCC methodologies and models?*
2. *Should weapon system program managers calculate their total ELCC?*
3. *What costs should weapon system program managers incorporate into their ELCC estimate?*
4. *What are the capabilities and shortcomings of current DoD ELCC methodologies and models?*
5. *What new DoD policies or guidelines should be implemented to assist weapon system program managers in using an ELCC methodology or model?*

6. *How should a weapon system program manager select or use an ELCC methodology or model?*

These research questions are answered in different areas of this chapter. The section that specifically addresses a research question is indicated in parenthesis and *Italics* after a section heading.

5.2 Summary

Calculating the ELCC of a DoD weapon system is complex. This section will discuss current DoD ELCC issues, methodology and model difficulties, methodology or model importance, current methodologies and models, and environmental cost categories.

5.2.1 Current DoD ELCC Issues. Environmental compliance and cleanup cost DoD approximately $3.4 billion dollars a year (22). The production, operation, maintenance, and disposal of weapon systems create the majority of the environmental costs (7, 4-5). In response to this problem, Congress enacted Public Law 103-337, requiring DoD to analyze the ELCC of all major weapon systems. DoD implemented regulations to analyze the ELCC of their major weapon systems, but many programs are not able to completely comply with this complex task. Weapon system programs face numerous challenges in calculating the ELCC of their program, and many of them do not have the proper resources or manpower to understand the complexity of environmental issues, laws, and policies.

5.2.2 ELCC Methodology and Model Difficulties. (*Research Question #1*) DoD faces seven major problems with the use of ELCC methodologies and models as described earlier in Section 2.6.6. The first problem deals with several general issues

with models and methodologies. ELCC models and methodologies might not be accepted, understood, or used improperly because of an over-simplification of the factors that drive environmental cost, a lack of interaction between developer and user, a lack of individual understanding / knowledge, no standardized ELCC framework, incorrect assumptions, or an individual bias. The other six problems with ELCC models and methodologies deal with changing or new environmental laws and policies, the complexity of weapon systems, undefined environmental cost categories, a lack of environmental cost data, the significant time line of a weapon system, and integrating the ELCC into the overarching LCC.

5.2.3 DoD ELCC Methodology or Model Importance. (*Research Question #2*) There are three major reasons why an ELCC methodology or model should be implemented for DoD weapon system programs. First, Public Law 103-337 states that Congress requires all DoD organizations to track the ELCC for all Major Defense Acquisition Programs (MDAP). Second, several governmental officials feel that calculating the ELCC for DoD MDAP is beneficial. Several speeches, hearings and the new DoD 5000 series discussed in Section 4.2.2 suggest that they are trying to implement policy that will require this to happen. Third, both civilian and military organizations have demonstrated that implementing an ELCC methodology or model has improved their organizations and allowed them to gain a better grasp of their environmental costs as shown in Section 4.2.3. None of these organizations documented any major problems or regrets for the amount of time and money required implementing their ELCC methodology or model. Developing an ELCC methodology or model for DoD weapon system programs will provide a systematic method for evaluating the ELCC of a program

and evaluating alternatives that can have substantial benefit for the life of the program and DoD in general.

5.2.4 DoD Environmental Cost Categories. (*Research Question #3*) Environmental cost categories must be clearly defined to evaluate the ELCC of a DoD weapon system. Environmental cost categories from three different sources (Army, Joint Strike Fighter, and DoD Cost Report) were analyzed and compared in Sections 4.3.1-4 using assessment criteria developed in Section 3.3.1. By analyzing how these different sources categorize their environmental costs, a comprehensive list of environmental cost categories was developed in Section 4.3.5 to ensure the most significant environmental costs are properly accounted for. These standardized environmental cost categories were then organized into a WBS format that takes into account different DoD appropriations or acquisition phases to follow the current DoD costing techniques. Any DoD weapon system program can now use this environmental work breakdown structure to determine their ELCC.

5.2.5 Current DoD ELCC Methodologies and Models. (*Research Question #4*)

DoD has not implemented a DoD-wide ELCC methodology or model for calculating the ELCC of its weapon system programs. DoD has delegated this responsibility to each weapon system program. Currently, there are only three significant models or methodologies used by DoD weapons system programs. They are the Army ELCC Methodology, Navy ELCC Model, and NDCEE ECAM. The Army ELCC Methodology provides an accounting structure to track environmental costs. The Navy ELCC model calculates environmental production, organizational and intermediate level maintenance, depot level maintenance, and demilitarization and disposal costs from

developed databases. NDCEE ECAM provides a consistent means of evaluating environmental costs and technologies that address compliance and pollution prevention issues. Even with these three ELCC methodologies and models, the majority of DoD weapon system programs do not calculate the ELCC of their program.

5.3 New Foundation

If DoD decides to implement a standardized ELCC methodology or model, it must overcome current problems. This section will first provide ELCC methodology and model policy guidance to the environmental policy making organization of DoD, DUSD (Environmental Security). Then this section will provide specific ELCC methodology and model selection and usage guidance for weapon system programs.

5.3.1 DoD Recommendations. (*Research Question #5*) DUSD(ES) needs to improve communication or provide more guidance to weapon system programs to reduce the amount of problems with calculating the ELCC of weapon system. DUSD(ES) should first determine what environmental cost information is needed by defining standardized environmental cost categories. Then DUSD(ES) should develop an overarching methodology or model to calculate the ELCC of a weapon system program. The next two sections provides recommendations on how DUSD(ES) should accomplish this task.

5.3.1.1 Standardized Environmental Cost Categories. DUSD(ES) should determine what weapon system environmental costs are important to capture (e.g., compliance, cleanup, conservation, pollution prevention, technology, etc.). From this information, DUSD(ES) should then develop a standardized list of environmental cost

categories (e.g., administrative, pollution prevention / waste management, production, operation and support, disposal and demilitarization, etc.) to organize these costs in manner that is useful to develop strategies or make decisions. Each one of these categories should then be subdivided into the different environmental media subcategories (e.g. air, hazardous materials, solid hazardous waste, noise, water / waste water, etc.) and specifically defined. Finally, examples of these should be listed. For example, administrative costs related air might include plans, reports, permits, tests, audits, and assessments. Section 4.3.4 provides a suggested format for a standardized list of environmental cost categories. Also, Chapter 6 in the Army Cost Analysis Manual provides an excellent format to help implement this plan.

The purpose of developing this list of environmental cost categories is to ensure that each weapon system program understands what environmental costs need to be calculated. DUSD should develop guidelines to implement the environmental cost category and media subcategories for weapon system programs. Each individual weapon system program should develop their specific environmental costs under each environmental media subcategory to account for the nuances of the program.

5.3.1.2 ELCC Methodology or Model. DUSD(ES) should adopt and issue guidance supporting the use of the Army ELCC Methodology, Navy ELCC Model, and NDCEE ECAM. The purpose for adopting more than one ELCC methodology or model is that each one has different capabilities. The next five paragraphs will explain the intricacies of the different ELCC methodologies and models and what environmental costs they track.

The ultimate purpose of an ELCC methodology or model is to track the environmental cost of a weapon system through each phase of the life cycle. Figure 5-1 depicts the environmental cost of a weapon system. The vertical rectangles with dashed lines represent the five phases of the weapon system life cycle: Concept Exploration (CE); Program Definition and Risk Reduction (PDRR); Engineering and Manufacturing Development (EMD); Production, Fielding, Operation and Support (O&S), and Demilitarization and Disposal (D&D). The horizontal rectangles with solid lines represent the five major appropriation categories used during the acquisition process: Research, Development, Testing, and Evaluation (RTD&E), Procurement (PROC), Operations and Maintenance (O&M), Military Personnel (MILPERS), and Military Construction (MILCON). This figure will be used again to display to explain how each ELCC methodology or model captures environmental costs during the acquisition life cycle.

The Army ELCC Methodology should be used to calculate the entire ELCC of each weapon system program. The Army ELCC Methodology provides a good overall accounting structure for weapon system programs to track their ELCC. One problem with the Army ELCC is that it does not specifically evaluate contractor environmental costs in the production and depot process. Figure 5-2 represents the environmental costs that can be calculated with the Army ELCC Methodology. The staggered line around the different appropriation category boxes demonstrates that the Army ELCC can account for most environmental costs, but there is error. The staggered line demonstrates two types of errors – under and over estimating. These are expected because it is impossible to

account for everything properly because of oversimplification or lack of perfect information.

The Navy ELCC Model should be used by major weapon systems that are in the PDRR, EMD, or early to middle stages of the O&S phase. This model provides a weapon system program an effective tool to evaluate their environmental production, operation and support, and disposal costs that addresses the weakness of the Army ELCC. In conjunction with the Army ELCC Methodology, this tool will help improve the ELCC estimate throughout the entire life cycle of the weapon system program. Figure 5-3 represents the environmental costs that can be calculated with the Navy ELCC Model. The staggered line around the different appropriation category boxes demonstrates that the Navy ELCC Model can account for most EMD, PDRR, Production, Fielding, O&S, and D&D environmental costs, but there are estimating errors. It also shows that the Navy ELCC Model does not account for most RDT&E and MILCON costs associated with the weapon system.

The use of NDCEE ECAM should be implemented to help weapon systems evaluating environmental costs and technologies that address compliance and pollution prevention issues. This methodology provides a logical and consistent means to evaluate future environmental costs and technologies throughout the entire life cycle of a weapon system program. This methodology can also be used to help determine what are the specific environmental cost drivers of an existing technology. In conjunction with the Army ELCC Methodology and Navy ELCC Model, this tool will also help improve the ELCC estimate throughout the entire life cycle of the weapon system program. Figure 5-4 represents the environmental costs that can be calculated with NDCEE ECAM. The

two separate sets of staggered lines around the different appropriation category boxes randomly demonstrate two different environmental technologies or alternatives evaluated by NDCEE ECAM. NDCEE ECAM can evaluate most environmental technologies or alternatives in any appropriation category or acquisition life cycle phase. As noted before, NDCEE is not designed to calculate the entire ELCC of a weapon system. Incorporating these ELCC methodologies and models provides a weapon system program with the ability to track all their environmental costs and evaluate specific environmental technologies or alternatives. Figure 5-5 shows the result of combining the capabilities of these ELCC methodologies and models. Not only are the majority of the environmental costs tracked, the most significant appropriation categories (PROC, O&M, and MILPERS) and life cycle phases (EMD, O&S, and D&D) can be analyzed in-depth with more detailed ELCC methodologies and models.

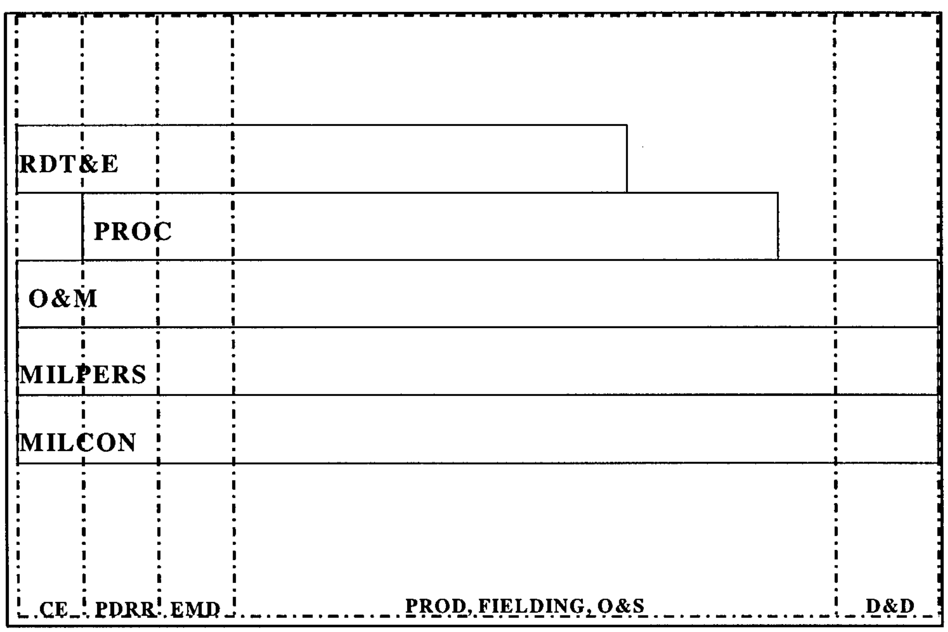

Figure 5-1. Acquisition Life Cycle Appropriations

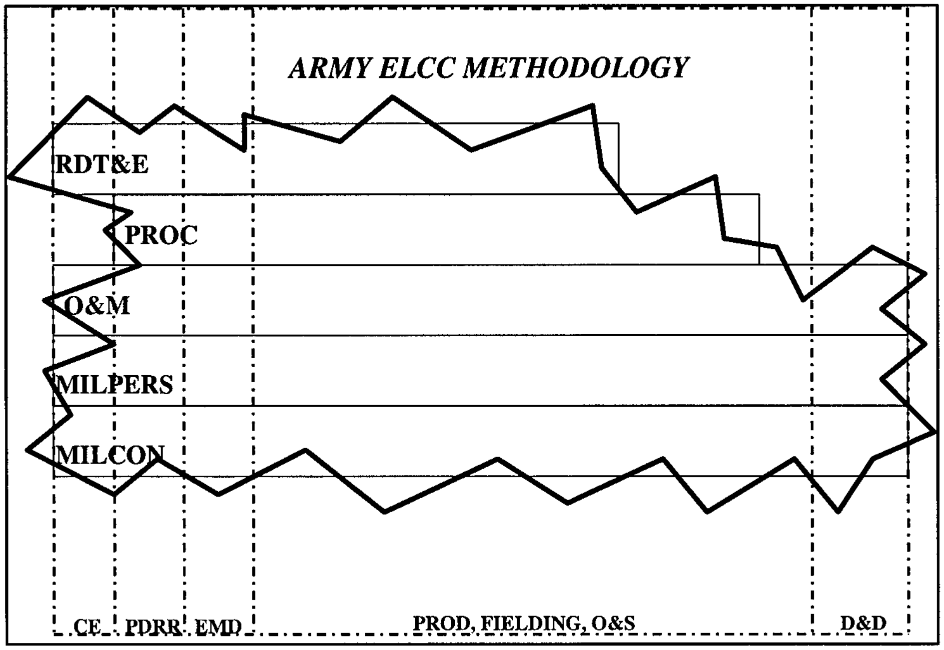

Figure 5-2. Army ELCC Methodology

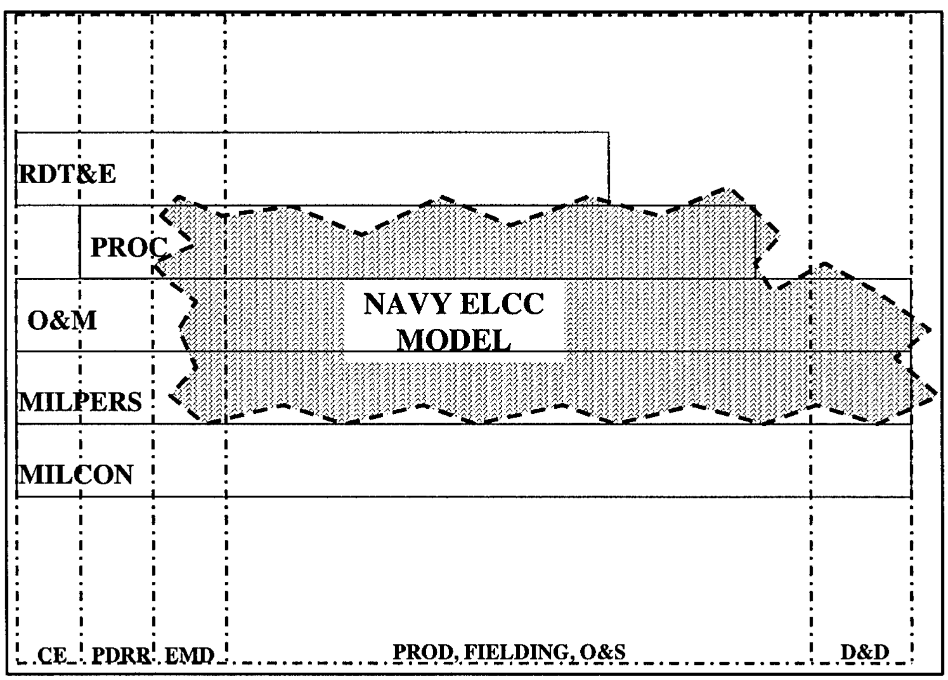

Figure 5-3. Navy ELCC Model

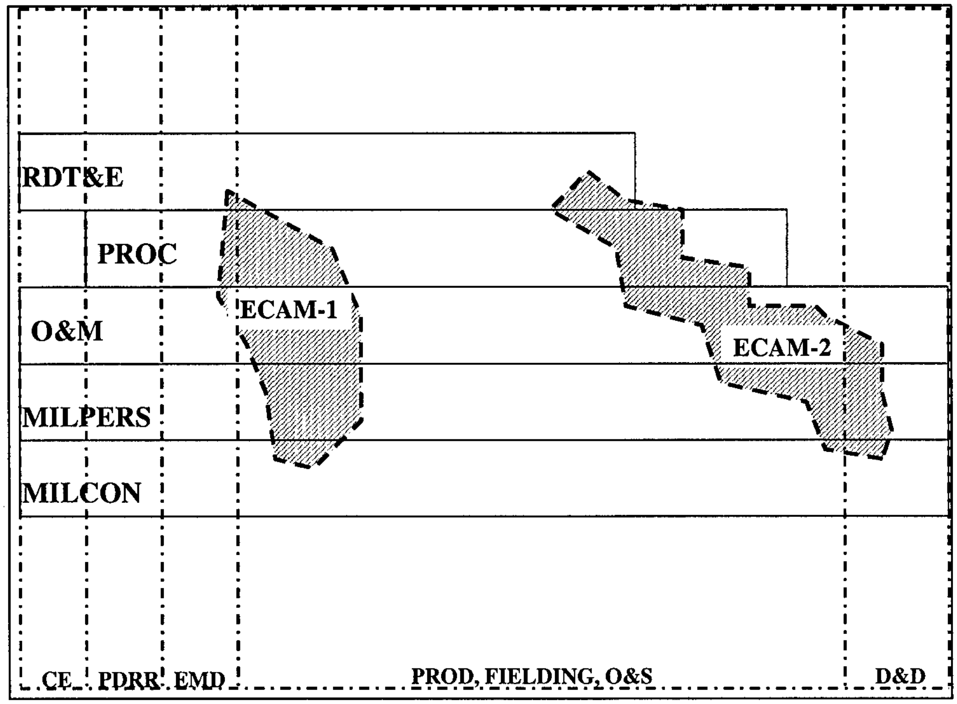

Figure 5-4. NDCEE ECAM

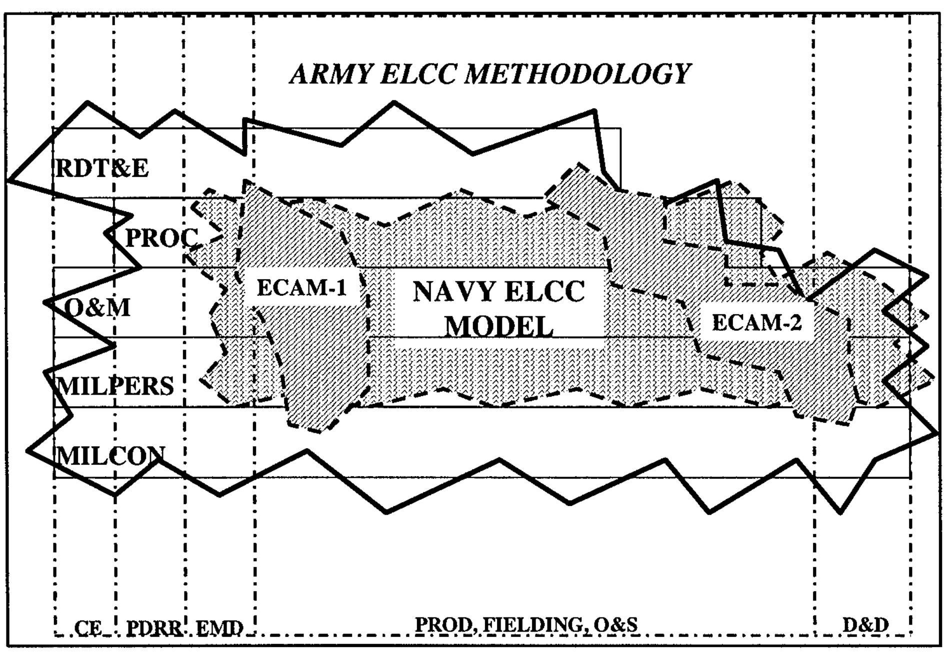

Figure 5-5. ELCC Methodology and Model Comparison

<u>5.3.2 Weapon System Program Recommendations.</u> (*Research Question #6*) This section is divided into two parts. The first part of this section provides recommendations on which ELCC methodology or model a weapon system program should use based if the current policy and guidance on the ELCC of a weapon system program is not changed by DUSD(ES). The second part of this section provides some recommendations and suggestions on how a weapon system should use an ELCC methodology or model.

5.3.2.1 Selecting an Environmental Life Cycle Cost Methodology. A weapon system program must determine what ELCC methodology or model best suits their needs. The most important factors in selecting an ELCC methodology or model are the age of the weapon system program and what they need the ELCC methodology or model to calculate. A weapon system program should implement the Army ELCC Methodology, Navy ELCC Model, and NDCEE ECAM if it is in the PDRR, EMD, or early to middle stages of the O&S phase – such as the JSF. The Army ELCC Methodology provides an overall environmental accounting structure to track their environmental costs. The Navy ELCC Model details the environmental costs of the production, operation, and maintenance activities and would help a program analyze these costs. NDCEE ECAM provides a method to evaluate specific environmental technologies or different alternatives. A weapon system in the middle to later stages of the O&S phase should probably only incorporate the Army ELCC Methodology and NDCEE ECAM. This would provide the weapon system program with an overall accounting structure to track their environmental costs and evaluate specific technologies

or different alternatives. Professional judgment should be used to determine if the Navy ELCC model would be cost effective if it is implemented late in the acquisition life cycle.

5.3.2.2 Using an Environmental Life Cycle Cost Methodology. Weapon system programs must be careful when using an ELCC methodology or model because of the same difficulties discussed in Section 2.6.6. This section will provide suggestions to overcome the difficulties of ELCC methodologies and models.

Prevent oversimplification – Ensure all necessary factors are included in an ELCC methodology or model when evaluating new technologies or different alternatives. Several different experts should be consulted or included in the analysis and decision making process to prevent oversimplification. Weapon systems are complex and changes can impact numerous performance characteristics, processes, personnel, and organizations associated with the program. For example, the decision to use an environmental friendly or hazardous paint on a tactical fighter aircraft impacts the performance characteristics, processes, personnel, and organizations associated with the weapon system program.

Adequate developer / user interaction – Ensure adequate interaction occurs between ELCC methodology and model developers and users. Contractors typically gather and analyze environmental cost data and develop new or implement existing ELCC methodologies and models. The contractor's work is typically then turned over to the government for future use. Make sure individuals using the ELCC methodology or model are properly trained and have access to help when needed. The ELCC methodology or model should also have detailed documentation explaining assumptions, data, calculations, and any other pertinent information.

Proper understanding / knowledge – Ensure individuals using an ELCC methodology or model have the technical background to understand or use the model. These individuals must understand the nuances (e.g. chemicals, materials, and processes) associated with the new technology or different alternatives. A weapon system program should ensure user-friendly instruction manuals or tutorials that clearly explain the important information relevant with the ELCC methodology or model are developed. This will help ensure users are properly trained and understand the ELCC methodology or model.

Document assumptions – Individuals must understand all assumptions when using an ELCC methodology or model to perform an analysis properly. All ELCC methodologies and models have assumptions of one sort or another. For example, the Navy ELCC uses environmental cost data from certain locations in the United States, therefore, an analyst must ensure the environmental technology or alternative they are evaluating is from one of these locations or use a cost-adjusting factor to account for the difference.

Manage data - One of the biggest difficulties with ELCC methodologies and models is data required to use them properly. Collecting and generating data can require an extensive amount of time and a significant amount of funding. Once the data collection is complete, organizations must continuously organize and maintain the data for it to remain current. Data should be analyzed every single time before it is used to ensure that it is applicable when trying to determine future costs or decisions. Finally, data is not always useful especially when new technologies are being evaluated. Weapon system programs must individually analyze what environmental cost data should be

tracked and determine if properly maintaining and updating this data is worth the cost. As discussed in Section 4.2.3.2, Boeing conducted a study and determined that historical data is not always the best predictor of future environmental costs.

Integrating the ELCC into the overarching LCC - Major reasons why ELCC methodologies and models are not accepted in DoD is because they are not integrated into the overarching LCC. ELCC is not the only factor a program manager uses when evaluating an alternative. The program manager looks at several different factors (performance, speed, etc.) and costs (material, production, operation, procurement, etc.). Therefore, for an ELCC methodology or model to be more effective, it needs to fit in with the overarching LCC. This will allow the program manager to make better and more informed decisions because they can see the effect the environmental factors have on the other factors in the weapon system.

5.4 Shortcoming and Limitations

There are several different ways to look at the ELCC of a weapon system program. This topic can be analyzed from several different viewpoints or professions - financial analyst, acquisition professional, acquisition executive, DoD official, service level staff, command level staff, center level staff, using agency, base support organization, defense contractor, politician, or an independent source. This thesis effort was conducted by a graduate student with base civil engineering experience and not directly tied to any of these organizations or professions.

The main shortcoming or limitation of this study is that three existing DoD ELCC methodologies or models could not be integrated and tested together. Every ELCC

methodology and model is different and requires different environmental cost data. Until DoD implements a specific ELCC methodology or model and develops a usable environmental cost database, it will be difficult to determine their accuracy or compare results.

5.5 Areas for Future Research

Several areas for future research can be pursued from this thesis effort. This section will focus on three major areas. The first area is the integration of the Army ELCC methodology, Navy ELCC Model, and NDCEE ECAM into a single ELCC methodology / model. The second area is the development of more definitive methodologies to account for environmental costs associated with unpredictable events (e.g., lawsuits, claims, and mishaps) and facilities (e.g. containment areas, safety equipment, etc.). The final area is the implementation and validation of the recommendations developed in Section 5.3.

Integrating the Army ELCC Methodology, Navy ELCC Model, and NDCEE ECAM would provide DoD with a single standardized software tool to calculate MDAP ELCC. This would require integrating the software systems, creating an environmental cost database, and developing a training manual. Most software systems can be adapted to accommodate the integration of the three ELCC methodologies and models; however, developing a shared environmental database is a huge undertaking. The complexity of the different weapon systems and the different technologies might make it infeasible to develop a single environmental cost database. DoD would have to determine if different

services, programs, or processes could share this environmental database. Then DoD would have to determine what environmental cost data should be collected for the calculation of the ELCC of a MDAP. Finally, DoD would need to understand the financial implications of developing and maintaining this environmental database.

Methodologies to calculate environmental costs associated with unpredictable events and facilities are not well developed. DoD has a lot of data and information on these subjects, but they have not compiled and specifically correlated to weapon systems. This would require finding and evaluating documentation on legal claims, safety equipment, facility designs, and other related issues to develop a handbook to consolidate this information for weapon system program managers. Having this information would help fine tune their ELCC estimates and allow them to analyze the potential financial risk associated with using particular environmental hazards.

The third and final area would be to implement and validate the recommendations provided by this thesis effort in Section 5.3. If DUSD(ES) implemented the recommendations of this thesis, the results should be periodically evaluated to ensure progress is made and if any adjustments are needed. DUSD(ES) should compare the results of different weapon system programs to see if there are any common issues or problems that need to be addressed. DUSD(ES) could also use this information to possibly streamline different environmental support organizations or processes to help reduce the overall budget. Finally, DUSD(ES) could use this evaluation to demonstrate to Congress the overall success of their environmental efforts or the need for additional support to help reduce environmental costs.

Appendix A – Acquisition Categories

There are three major DoD acquisition categories for Air Force weapon system programs: ACAT I, ACAT II, and ACAT III. Note: there is also category called ACAT IV, but the Air Force does not use this category. Table A-1 lists the RDT&E and Procurement Levels and the Major Decision Authority (MDA) that determine the weapon system acquisition categories. ACAT I programs are considered Major Defense Acquisition Programs (MDAP) and major systems. ACAT I programs are also divided into two subcategories called ACAT ID and ACAT IC depending on the level of approval (D for DoD approval required and C for service component approval required). ACAT II programs are those not defined as ACAT I programs, but do meet the criteria for a major system. ACAT III programs are defined as those acquisition programs that do not meet the criteria for ACAT II programs. (13, 4.6-4.8)

Table A-1. Weapon System Acquisition Categories (15, 34)

Category	RDT&E Level (FY 00 dollars)	Procurement Level (FY 00 dollars)	Major Decision Authority (MDA)
ACAT ID	$365M	$2.19B	DAE
ACAT IC	$365M	$2.19B	Service Secretary or CAE
ACAT II	$140M	$660M	Service Secretary or CAE
ACAT III	<$135M	<$640M	Appointed by CAE

Appendix B - Current Acquisition Life Cycle

The Current Acquisition Life Cycle will be phased-out in the next couple of years. Below is a chronologically ordered description of each phase and milestone of this life cycle (13, 4.1:4.6). Figure B-1 depicts the acquisition life cycle.

- **Determination of Mission Need -** This is not a formal phase of the process, but it is where the mission needs or requirements are established by the users.
- **Milestone 0** - The first decision point is used to determine if the *Determination of Mission Need* requires additional study and should enter the next phase of the process.
- **Concept Exploration (Phase 0)** – In this phase an *Analysis of Alternatives* is completed to select a conceptual approach that will satisfy the mission needs or requirements of the user in the most cost-effective manner. Based on the results of this analysis, the user develops an *Operational Requirements Document* which describes the their minimum acceptable thresholds and objectives (i.e. speed, range, etc.).
- **Milestone 1** – The second decision point is used to determine whether to start a new acquisition program to meet the user's need or requirement.
- **Program Definition and Risk Reduction (Phase I)** – This phase is used to demonstrate and validates that the technological capability is achievable within the required timeframe and available resources.
- **Milestone 2** – The third decision point is used to determine if the program is ready to proceed into the Engineering and Manufacturing Development Phase.
- **Engineering and Manufacturing Development (Phase II)** – This phase is used to finalize the system design and ensures that the manufacturing processes are ready for full-scale production.
- **Milestone 3** – The fourth and final decision point is used to determine whether the weapon system is ready for full-scale production.
- **Production, Fielding / Deployment, and Operational Support (Phase III)** – This phase is used to focus on manufacturing the weapon system, fielding / deploying the weapon system to the users, and training the users to operate and maintain the weapon system.

- **Demilitarization and Disposal** – At the end of their useful life, weapon systems must be demilitarized and disposed of properly.

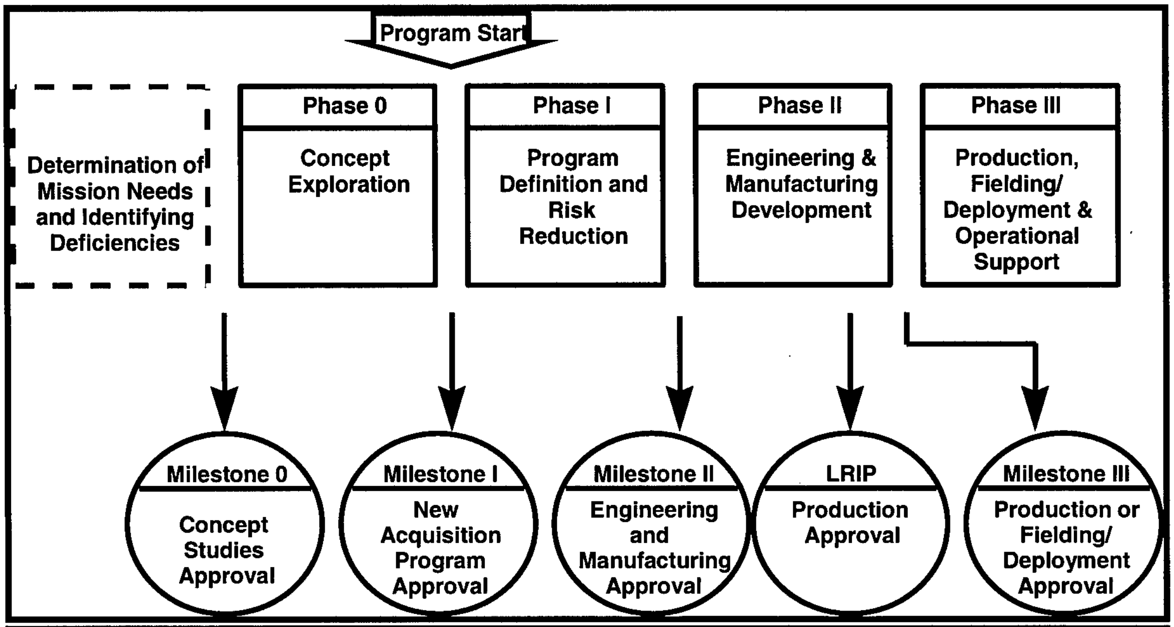

Figure B-1. Current Acquisition Life Cycle (10, 14)

Appendix C – New Acquisition Life Cycle

The New Acquisition Life Cycle will be phased-in in the next couple of years. The New Acquisition Life Cycle is developed around a framework of three activities: Pre-systems acquisition, Systems Acquisition, and Sustainment. Below is a chronologically ordered description of each phase and milestone of this life cycle (15, 7:26). Figure C-1 depicts the acquisition life cycle and shows how the framework and phases are incorporated

- **Development of User Needs -** This is not a formal phase of the process, but it is where the mission needs or requirements are established by the users.

- **Milestone A** - The first decision point is used to approve the initial concept studies and the exit criteria for the Concept and Technology Development Phase.

- **Concept and Technology Development Phase** – This phase consists of paper studies of alternative concepts for meeting needs, development of subsystems / components that must be demonstrated before integration into a system, and a demonstration of new system concepts.

- **Milestone B** – The second decision point is normally used to determine whether to start a new acquisition program. The main purpose of this decision point is to authorize the entry into the System Development and Demonstration Phase.

- **System Development and Demonstration Phase –** The phase is used to develop a system, reduces program risk, ensures operational supportability, designs for producibility, assures affordability, and demonstrates system integration, interoperability, and utility.

- **Milestone C** – The third decision point is used to determine whether to authorize entry into low-rate initial production.

- **Production and Deployment Phase** – This purpose of this phase is to achieve an operational capability that satisfies mission needs.

- **Full Rate Production (FRP) Decision Review** - After low-rate initial production is completed, the PM must receive additional approval from the MDA to initiate full-rate production.

- **Operation and Support Phase** – This phase consists of the sustainment and disposal of the weapon system.

- **Follow on Blocks for Evolutionary Acquisition** - Subsequent definition, development, test and production/deployment of weapon systems beyond the initial capability over time.

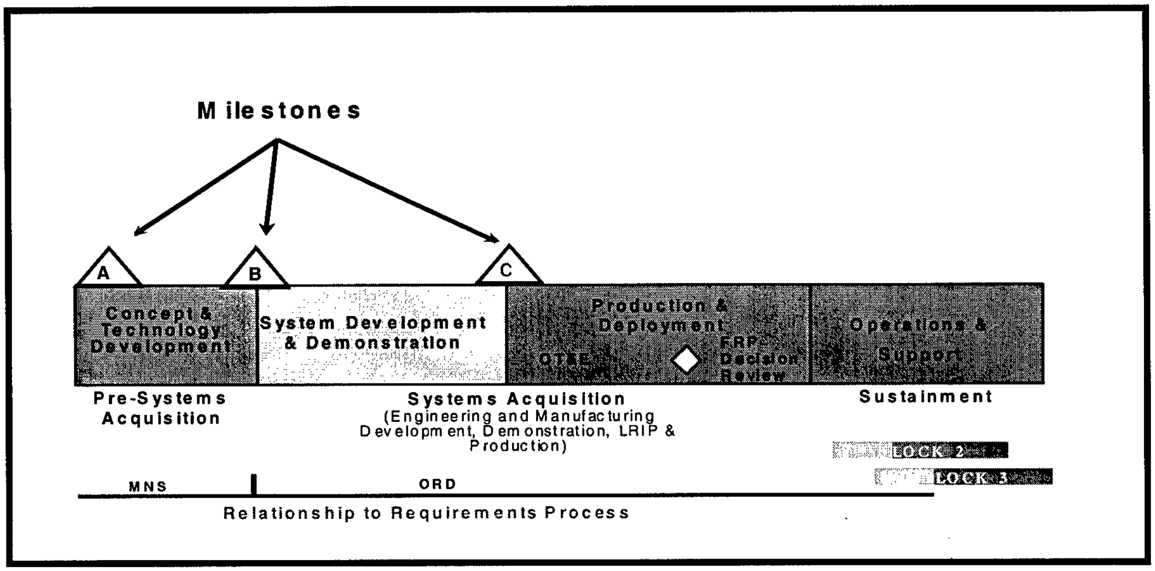

Figure C-1. New Acquisition Life Cycle (15, 7)

Appendix D - Example Work Breakdown Structure

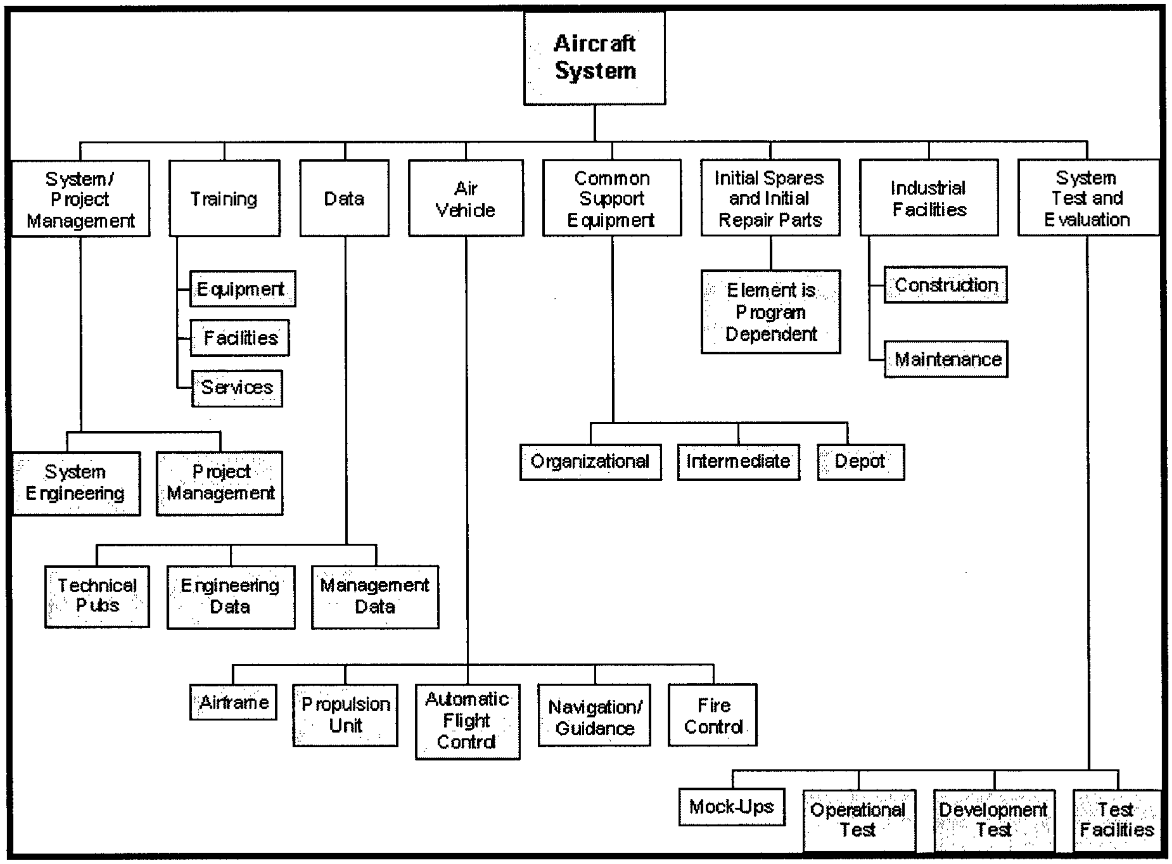

Figure D-1. Work Breakdown Structure (6, 10.4)

Appendix E – Acquisition Authorities and Policies

E.1 The Law

Congress grants DoD the statutory authority that provides the legal basis for weapon systems acquisition. Congress is also responsible for the annual authorization and appropriations legislation, which also places additional statutory requirements on DoD. Below is a list of the most prominent laws that govern DoD acquisitions:

- Armed Services Procurement Act (1947), as amended
- Small Business Act (1963), as amended
- Office of Federal Procurement Policy Act (1983)
- Competition in Contracting Act (1984)
- DoD Procurement Reform Act (1985)
- DoD Reorganization Act of 1986 (Goldwater-Nichols)
- Government Performance and Results Act (1993)
- Federal Acquisition Streamlining Act (1994)
- Clinger – Cohen Act of 1996. (23, 8)

E.2 Executive Directives

The Executive Branch also provides authority and guidance to DoD in the form of executive orders, national security decision directives, and other agency regulations. Below is a list of the most prominent Executive Directives that govern DoD acquisitions:

- Executive Order 12352 (1982)
- Federal Acquisition Regulation (FAR) (1984)
- National Security Decision Directive 219 (1986)
- Executive Order 13011 (1996)

- OMB Circular A-11 (1997) describes the budget. (23, 9)

E.3 DoD Acquisition Policy Documents

The three major DoD Acquisition Policy Documents are DoD Directive 5000.1, *Defense Acquisition*, DoD Instruction 5000.2, *Operation of the Defense Acquisition System*, and DoD Regulation 5000.2-R, *Mandatory Procedures for Major Defense Acquisition Programs and Major Automated Information System Acquisition Programs.* DoD Directive 5000.1 provides policies and procedures for all DoD acquisition programs and identifies the major responsibilities of the key acquisition officials. DoD Instruction 5000.1 and DoD Regulation 5000.2-R establish a management framework with mandatory policies and procedures in order to translate mission needs into well-managed acquisition programs. (23, 28:32)

Appendix F – Acquisition Organizations

F.1 The Congress

The major players in Congress include the Senate / House authorizing committees (Armed Services), Senate / House Appropriations Committees, Senate / House Budget Committees, various other committees having legislation oversight on defense activities, individual members of Congress having interest on defense activities, Congressional Budget Office, and the General Accounting Office. The major responsibilities of the Congress in weapon system acquisition are to debate and pass legislation, conduct hearings, set limits (manpower and equipment), raise taxes, provide funds, and establish oversight committees. Their objectives are to balance defense and social needs, distribute dollars by district or state, control public debt, maximize competition, and control mismanagement. (23, 4)

F.2 Executive Branch

The major players within the Executive branch are the President, DoD, the Office of Management and Budget, the Department of State, and the National Security Council. The major responsibilities of the Executive Branch in weapon system acquisition are to sign legislation into law, contract with industry, negotiate with Congress, and make decisions on major defense acquisition programs. Their objectives are to satisfy national security needs, maintain a balanced force structure, and avoid congressional or public scrutiny. (23, 3)

F.3 Industry

The major players for industry include contractors from organizations (large and small), both foreign and domestic that provide goods and services to DoD. The major

responsibilities of Industry in weapon system acquisition are to respond to solicitations, propose solutions, conduct independent studies, and design/produce/maintain/upgrade systems. Their objectives are profit, growth, stability, and technological achievement. (23, 5)

F.4 DoD Acquisition Organization

The acquisition organization for DoD is complex. Below is a list of the major organizations involved in this process. Figure F-1 provides an organization chart that depicts the typical chain of command.

- Secretary of Defense – ultimately responsible for all acquisition programs.
- Office of the Secretary of Defense – staff that helps the Secretary of Defense manage DoD.
    - Under Secretary of Defense, Comptroller (USD(C))– controls the budget and release of funds.
        - Director, Program Analysis & Evaluation (DPAE) – conducts program analysis and ensures money is spent properly and in a timely manner.
    - Under Secretary of Defense, Policy (USD(P)) – responsible for planning phase and programs involving other nations.
        - Director, Operational Test & Evaluation (DOTE) – independently assesses operational effectiveness and suitability of new weapon systems.
    - Under Secretary of Defense, Acquisitions, Technology, and Logistics (USD(AT&L)) – establishes policy and procedures for DoD acquisition programs. Also known as the Defense Acquisition Executive (DAE).
- Secretary of the Army, Navy, and Air Force – responsible for their respective service.
    - Under Secretary of Acquisition – establishes policy and procedures for their respective service's acquisition procedures. Also known as the Component Acquisition Executive (CAE).

- Program Executive Officer (PEO) – responsible for several Weapon System Programs (i.e. fighters, bombers, tanks, etc.). Reports to Material / System Command and Service Under Secretary of Acquisition.

- Weapon System Program Manager (PM) – responsible for a single Weapon System (i.e. Joint Strike Fighter, F-16, etc.). Reports to Program Executive Officer and Service Under Secretary of Acquisition.

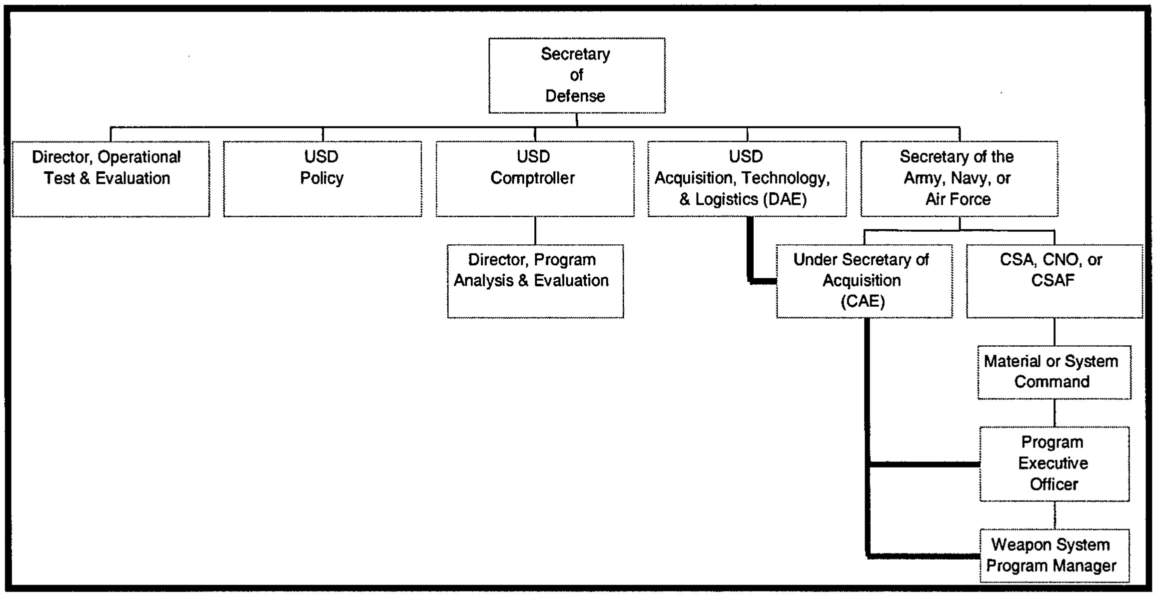

Figure F-1. DoD Acquisition Organization Chart

There are also several boards / councils that are key players in Defense acquisition. They include:

- Defense Acquisition Board (DAB) – forum that advises USD (A&T) on critical issues facing ACAT ID programs. Members include Vice Chairman Joint Chiefs of Staff, Component Under Secretaries of Acquisition, USD(C), DPAE, DOTE, PEO, PM, and others.

- Defense Resources Board (DRB) – DoD's principal resource management organization. Chaired by Deputy Secretary of Defense and members include USDs, DPAE, Secretaries of military departments, and the Chairmen and Vice Chairmen of the Joint Chiefs of Staff.

- Joint Requirements Oversight Council (JROC) - validates and approves requirements for ACAT I and ACAT II programs. Chaired by Vice Chairman of the Joint Chiefs of Staff and members include Vice Chief of Staffs of each service.

- Cost Analysis Improvement Group (CAIG) – provides an Independent Cost Estimates of an ACAT ID program's life cycle cost prior to each milestone review. Chartered by DPAE. (DSMC, 35:47)

Appendix G - Major Environmental Laws and Regulations

Table G-1. ESH Laws (7)

ESH Law	Description	Impact To Program/Single Manager
National Environmental Policy Act (NEPA), 1970	Requires federal agencies to consider environmental impacts in decision making	PM/SM are proponents of NEPA documentation; SAF/AQRE approves all AF weapon systems NEPA documentation; failure to comply with NEPA may cause program delays and stoppages
Clean Air Act (CAA), 1963,..., 1990	Established Air Quality Standards For Six (6) Criteria Pollutants And Requires Control Technology And Programs In-Accordance-With (IAW) Standard Industry Procedures (sips)	CAA Drives State and Local Air Regulations Which May Impact Basing Locations For Weapon Systems
Clean Water Act (CWA), 1972	Controls discharge of pollutants into waters if the united states, wastewater treatment	CWA may impact basing locations for weapon systems
Public Law 102-484, Sections 325 & 326	Evaluation Of Class I & II ODSS And Elimination Of Class I ODSS	Must Be Considered When Incorporating Pollution Prevention (P2) Studies Into The Systems Engineering Process
Public Law 103-337, Section 815	(1) how to achieve the purpose and intent of NEPA; (2) how to analyze life cycle environmental costs; (3) analyze MDAP environmental costs no later than march 31, 1995	Must analyze MDAP ESH costs
Resource Conservation And Recovery Act (RCRA), 1976	Regulates on-going hazardous waste handling and disposal, including permitting requirements	RCRA should be considered when incorporating pollution prevention (P2) studies into the systems engineering process
Pollution Prevention Act (PPA), 1990	Institutes national policy of us that pollution should be prevented or reduced at the source whenever feasible	PPA should be considered when incorporating pollution prevention (P2) studies into the systems engineering process
Toxic Substances Control Act (TSCA), 1976	Regulates manufacture, distribution, use and disposal of chemicals	TSCA should be considered when incorporating pollution prevention (P2) studies into the systems engineering process
Occupational Safety And Health Act (OSH Act), 1970	Ensures safe and healthful conditions for the nations workforce	OSH act should be considered when incorporating pollution prevention (P2) studies into the systems engineering process
Federal Facilities Compliance Act (FFCA), 1992	Makes federal facilities and workers liable for fines and penalties under RCRA	Minimal, impacts supporting and using community primarily
Comprehensive Environmental Response, Compensation & Liability Act (CERCLA), 1980	Regulates the cleanup and remediation of hazardous waste sites	Minimal, impacts supporting and using community primarily
Emergency Planning And Community Right-To-Know Act (EPCRA), 1986	Requires toxic chemical release, inventory reporting and emergency planning	Minimal, impacts supporting and using community primarily. See EO 12969

Table G-2. Environmental Executive Orders (7)

Executive Order (EO)	Description	Impact To Program/Single Manager
EO 11514, Protection And Enhancement Of Environmental Quality, 05 Mar 1970	Federal agencies shall initiate measures needed to direct their policies, plans and programs so as to meet national environmental goals	Must be considered for incorporation into the systems engineering process
EO 12114, Environmental Effects Abroad Of Major Federal Actions, 04 Jan 1979	Federal agencies shall apply NEPA with respect to the environment outside the united states, its territories and possessions	Must consider NEPA impacts when weapon system is based outside united states
EO 12196, Occupational Safety And Health Programs For Federal Employees, 26 Feb 1980	Federal Agencies Must Furnish Employees Places And Conditions Of Employment That Are Free From Recognized Hazards That Are Causing or Are Likely To Cause Death Or Serious Physical Harm	Must Be Considered For Incorporation Into The Systems Engineering Process
EO 12780, Federal Agency Recycling And The Council On Federal Recycling And Procurement Policy, 31 Oct 1991	Requires federal agencies to promotes cost effective pollution prevention, cost effective waste reduction, and immediate implementation of cost effective federal procurement preference programs	Must be considered for incorporation into the systems engineering process
EO 12856, Federal Compliance With Right-To-Know Laws And Pollution Prevention Requirements, 03 Aug 1993	Describes the requirements and provisions for the establishment of pollution prevention programs within federal agencies	Must be considered for incorporation into the systems engineering process
EO 12873, Federal Acquisition, Recycling, And Waste Prevention, 20 Oct 1993	Federal agencies shall comply with executive branch policies for the acquisition and use of environmentally preferable products and services and implement cost effective procurement preference programs	Must be considered for incorporation into the systems engineering process
EO 12969, Federal Acquisition And Community Right-To-Know, 08 Aug 1995	Invokes EPCRA toxic release inventory (tri) reporting for contracts expected to exceed $100k	Must be considered for incorporation into the systems engineering process

Table G-3. DoD Environmental Requirements (7)

DoD Requirement	Description	Impact To Program/Single Manager
DoD 5000.2-R, Part 3, Section 3.3.6 -- Environmental, Safety, and Health Considerations	The acquisition strategy shall include a programmatic environmental, safety, and health (ESH) evaluation. The PM shall initiate the evaluation at the earliest possible time in support of a program initiation decision (usually milestone i) and shall maintain an updated evaluation throughout the life-cycle of the program.	Must perform a programmatic ESH evaluation. The programmatic ESH evaluation describes the PM's strategy for meeting ESH requirements (section 4.3.7), establishes responsibilities, and identifies how progress will be tracked
DoD 5000.2-R, Part 4, Section 4.3.7 -- Environmental, Safety, and Health	All programs, regardless of acquisition category, shall comply with this section and be conducted in accordance with applicable federal, state, and local environmental laws and regulations, executive orders, treaties, and agreements. ESH analyses shall be conducted to integrate ESH issues (NEPA, environmental compliance, system safety and health, hazardous materials, pollution prevention) into the systems engineering process and to support development of the programmatic ESH evaluation (section 3.3.6).	Must be incorporated into the systems engineering process
DoDD 4210.15 -- Hazardous Material Pollution Prevention (HMMP)	Hazardous Materials Shall Be Selected, Used, And Managed Over Its Life Cycle So That DoD Incurs The Lowest Cost Required To Protect Human Health And The Environment.	Must Generate A Hazardous Material Management Plan
DoD 5000.4M -- Department of Defense Manual Cost Analysis Guidance Procedures	Cost analysis requirements description (CARD) • provides a basis for cost estimating weapon system • provides a description of the salient features of the program and of the system being acquired	Must generate a card and provides PM opportunity to reflect and quantify the ESH requirements into the weapon system
MIL-STD-882C -- System Safety Program Requirements	This standard provides uniform requirements for developing and implementing a system safety program of sufficient comprehensiveness to identify the hazards of a system and to impose design requirements and management controls to prevent mishaps	Applies to all DoD systems and facilities as well as to every activity of the system life cycle

Table G-4. Air Force Environmental Requirements (7)

Air Force Requirement	Description	Impact To Program/Single Manager
AFPD 32-70 -- Environmental Quality, 15 Oct 1993	Specifies steps Air Force will take in regards to: cleanup, compliance, conservation, and pollution prevention	Must be implemented into weapon system over life cycle
AFI 32-7061 -- The Environmental Impact Analysis Process, 24 Jan 1995	Air Force procedural implementation of NEPA and council on environmental quality (CEQ) regulations	Must be implemented into weapon system over life cycle
AFI 32-7080 -- Pollution Prevention Program, 12 May 1994	Provides framework on how air force does business to comply with requirements according to AFPD 32-70 and outlines structure for pollution prevention management plans, measurement, hazardous substance management, and research and development	Must be implemented into weapon system over life cycle
AFPD 90-8 – Command Policy on Environmental, Safety, and Occupational Health, 1 Jan 1999	Establishes air force ESOH program.	Implement policy by integrating ESOH considerations into acquisition policies
AFPD 91-2 -- Safety Programs, 28 Sep 1993	The Air Force is committed to providing safe healthful environments both for air force people and for those affected by air force operations	Must be implemented into weapon system over life cycle
AFPD 91-3 -- Occupational Safety and Health, 27 Sep 1993	The Air Force is committed to providing safe and healthful workplaces to preserve their human resources	Must be implemented into weapon system over life cycle
AFI 91-301 -- Air Force Occupational and Environmental Safety, Fire Protection, and Health (AFOSH) Program, 01 Jun 1996	Minimize loss of Air Force resources and to protect air force people from occupational deaths, injuries, or illnesses by managing risks	Must be implemented into weapon system over life cycle
Eastern and Western Range Regulation 127-1, Range Safety Standards, Nov 1995	To provide for the public safety, the ranges, using a range safety program, must ensure that the launch and flight of launch vehicles and payloads present no greater risk to the general public than that imposed by the overflight of conventional aircraft	Must be implemented into weapon system over life cycle
Environmental, Safety, and Health (ESH) Evaluation Guide, Nov 1996	Provides overview of what is an ESH evaluation; who should be involved in performing the ESH evaluation; where ESH information should be contained; documenting the ESH evaluation and; strategy for preparing the ESH evaluation	Must be performed for weapon system over life cycle

Appendix H - Public Law 103-337, Section 815 (46)

ENVIRONMENTAL CONSEQUENCE ANALYSIS OF MAJOR DEFENSE ACQUISITION PROGRAMS

(a) GUIDANCE- Before April 1, 1995, the Secretary of Defense shall issue guidance, to apply uniformly throughout the Department of Defense, regarding--

(1) how to achieve the purposes and intent of the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.) by ensuring timely compliance for major defense acquisition programs (as defined in section 2430 of title 10, United States Code) through (A) initiation of compliance efforts before development begins, (B) appropriate environmental impact analysis in support of each milestone decision, and (C) accounting for all direct, indirect, and cumulative environmental effects before proceeding toward production; and

(2) how to analyze, as early in the process as feasible, the life-cycle environmental costs for such major defense acquisition programs, including the materials to be used, the mode of operations and maintenance, requirements for demilitarization, and methods of disposal, after consideration of all pollution prevention opportunities and in light of all environmental mitigation measures to which the department expressly commits.

(b) ANALYSIS- Beginning not later than March 31, 1995, the Secretary of Defense shall analyze the environmental costs of a major defense acquisition

process as an integral part of the life-cycle cost analysis of the program pursuant to the guidance issued under subsection (a).

(c) DATA BASE FOR NEPA DOCUMENTATION- The Secretary of Defense shall establish and maintain a data base for documents prepared by the Department of Defense in complying with the National Environmental Policy Act of 1969 with respect to major defense acquisition programs. Any such document relating to a major defense acquisition program shall be maintained in the data base for 5 years after commencement of low-rate initial production of the program.

Appendix I - DoD 5000.2-R, Section 4.3.7 (24)

4.3.7. Environment, Safety, and Health

All programs, regardless of acquisition category, shall comply with this section and be conducted in accordance with applicable federal, state, interstate, and local environmental laws and regulations, Executive Orders (EOs), treaties, and agreements. Environmental, safety, and health (ESH) analyses shall be conducted, as described below, to integrate ESH issues into the systems engineering process and to support development of the Programmatic ESH Evaluation.

4.3.7.1. National Environmental Policy Act

The PM shall comply with the National Environmental Policy Act (NEPA) (42 USC 4321-4370d[i]), implementing regulations (40 CFR 1500-1508), and executive orders (EO 12114 and EO 11514[iv] by analyzing actions proposed to occur in upcoming program phases that may require NEPA or EO analysis and providing the MDA with milestones and status for each planned analysis. Any analysis required under either NEPA or EO must be completed before the appropriate official may make a decision to proceed with a proposed action that may affect the quality of the human environment. NEPA and EO analysis is tied to proposed, program-specific actions. NEPA and EO documentation shall be prepared in accordance with DoD Component implementation regulations and guidance. The CAE is the final approval authority for system-related NEPA and EO documentation. The PM shall forward a copy of final NEPA documentation for ACAT I programs to the Defense Technical Information Center for archiving.

4.3.7.2. Environmental Compliance

Environmental regulations are a source of external constraints that must be identified and integrated into program execution. *To minimize the cost and schedule risks that changing regulations represent, the PM shall regularly review environmental regulations and shall analyze the regulations and evaluate their impact on the program's cost, schedule, and performance.*

4.3.7.3. System Safety and Health

The PM shall identify and evaluate system safety and health hazards, define risk levels, and establish a program that manages the probability and severity of all hazards associated with development, use, and disposal of the system. All safety and health hazards shall be managed consistent with mission requirements and shall be cost-effective. Health hazards include conditions that create significant risks of death, injury, or acute chronic illness, disability, and/or reduced job performance of personnel who produce, test, operate, maintain, or support the system. Each management decision to accept the risks associated with an identified hazard shall be formally documented. The CAE shall be the final approval authority for acceptance of high risk hazards. All participants in joint programs shall approve acceptance of high risk hazards. Acceptance of serious risk hazards may be approved at the PEO level.

EO 12196 and DoDI 6055.1 make Federal Occupational Safety and Health Act regulations applicable to all federal employees working in non-military-unique DoD operations and workplaces, regardless of whether work is performed by military or civilian personnel. In the case of military-unique equipment, systems, operations, or

workplaces, Federal safety and health standards, in whole or in part, apply to the extent practicable.

4.3.7.4. Hazardous Materials

The PM shall establish a hazardous material management program that ensures appropriate consideration is given to eliminating and reducing the use of hazardous materials in processes and products rather than simply managing pollution created (EO 12856). *The selection, use, and disposal of hazardous materials shall be evaluated and managed so the DoD incurs the lowest cost required to protect human health and the environment over the system's life-cycle, consistent with the program's cost, schedule, and performance goals.* Where a hazardous material use cannot be avoided, the PM shall plan for later material replacement capability in the system design, if technically feasible and economically practical and shall develop and implement plans and procedures for identifying, minimizing use, tracking, storing, handling, and disposing of such materials and equipment.

4.3.7.5. Pollution Prevention

In designing, manufacturing, testing, operating, maintaining, and disposing of systems, all forms of pollution shall be prevented or reduced at the source whenever feasible. Pollution that cannot be prevented shall be recycled in an environmentally safe manner. Pollution that cannot be prevented or recycled shall be treated in an environmentally safe manner. Disposal or other releases to the environment shall be employed only as a last resort and must be conducted in an environmentally safe manner. *The PM shall establish a pollution prevention program to help minimize environmental impacts and the life-cycle costs associated with environmental compliance.* The PM shall identify the impacts

of the system on the environment, wastes released to the environment, ESH risks associated with using new technologies, and other information needed to identify source reduction and recycling opportunities. Many opportunities for pollution prevention can be incorporated into contract documents. *In developing work statements, specifications, and other product descriptions, EO 12873 requires PMs to consider elimination of virgin material requirements, use of recovered materials, reuse of products, life-cycle cost, recyclability, use of environmentally preferable products, waste prevention (including toxicity reduction or elimination), and ultimately, disposal, as appropriate.*

Appendix J – DoD Organizations Involved with Environmental Issues

The number of organizations and professionals (i.e. environmental, safety, health, finance, program management, engineering, etc.) involved with environmental issues is staggering. Many of these organizations lack the necessary manpower or professionals and depend on other support organizations to provide proper environmental guidance. Below is a list of most of the organizations that participate in just environmental management and supporting activities. Figure J-1 provides an organization chart that depicts the organizations involved with environmental issues.

- Office of the Secretary of Defense
  - USD(AT&L) – establishes policy and procedures for DoD acquisition programs.
    - PDUSD(A&T) – responsible for DoD acquisition programs.
    - DUSD(ES) – responsible for DoD environmental programs.
  - USD(C) – controls the budget and release of funds.
    - DPAE – conducts program analysis and ensures money is spent properly and in a timely manner.
- Office of the Secretary of the Air Force
  - SAF/AQ – establishes policy and procedures for Air Force's acquisition programs.
    - SAF/AQRE – responsible for ESH issues during the acquisition process.
  - SAF/MI – responsible for Air Force manpower, personnel, installations, and environment.
    - SAF/MIQ – responsible for ESH issues in operations.
  - SAF/FM – responsible for Air Force financial management.

        - SAF/FMC – responsible for developing and implementing policy and procedures for cost estimating and analysis.

- Chief of Staff of the Air Force

    - HQ AFMC

        - AFMC Staff – coordinates, establishes, and executes AFMC policies and procedures in the following disciplines: engineering, environmental, safety, and financial management.

        - Product (ASC, ESC, HSC, SMC), Logistic, Test, and Specialized Centers

        - Weapons System Program Manager – responsible for a single Weapon System.

        - Functionals – coordinates, establishes, and executes Center policies and procedures in the following disciplines: engineering, environmental, safety, and financial management.

        - PEO – responsible for several Weapon System programs

    - Air Staff– coordinate, establish, and execute Air Force policies and procedures in the following disciplines: acquisition, environmental, safety, and financial management.

    - Other Major Commands (ACC, AMC, etc.) – coordinates, establishes, and executes command-level policies and procedures in the following disciplines: environmental, safety, and financial management.

        - Base level commands

            - User – operates and maintains weapon system.

            - Base Agencies– coordinates, establishes, and executes base-level policies and procedures in the following disciplines: environmental, safety, and financial management.

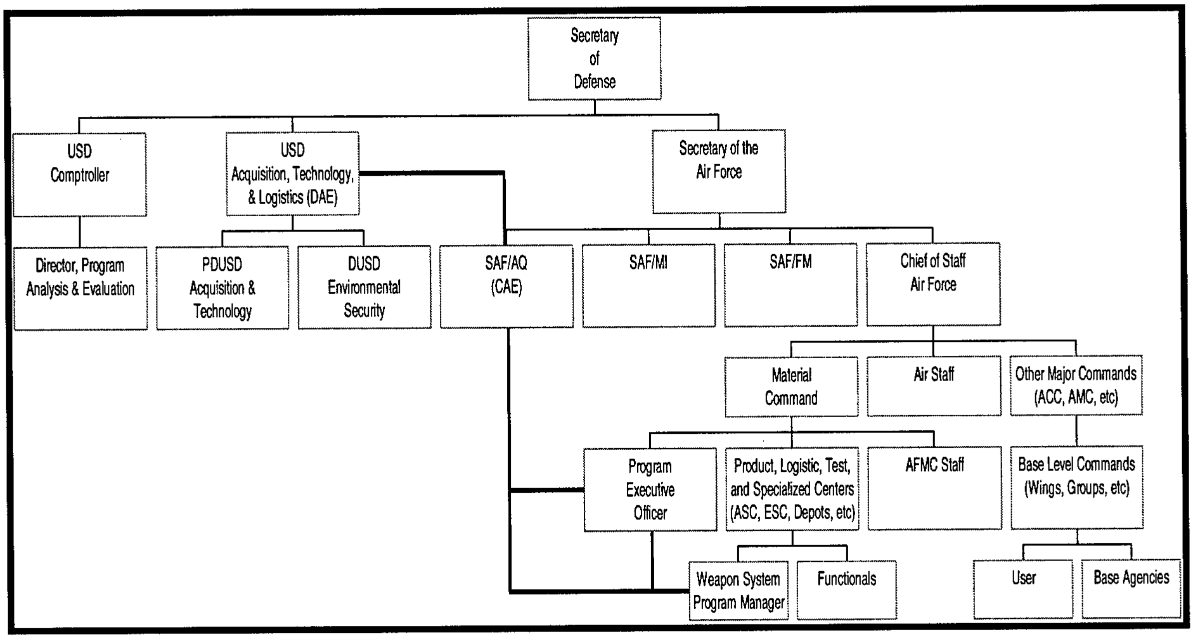

Figure J-1. DoD Organizations Involved in Environmental Issues.

Appendix K – Potential Mapping of ESH Costs to Acquisition Phase WBS Elements

Table K-1. Potential Mapping of ESH Costs to Acquisition Phase WBS Elements.

ESH Cost	Phase 0-III WBS	Phase III/D&D WBS
Analysis environmental impact	System Engineering/Pgm Management (SE/PM)	Sustaining Support, Engineering
Analysis of ESH alternatives	SE/PM	Sustaining Support, Engineering
Analysis, system safety hazard	SE/PM	Sustaining Support, Engineering
Assessments, ESH	SE/PM	Sustaining Support, Engineering
Contributions to common initiatives	SE/PM	Sustaining Support, Engineering
Disposal services specialized	Hardware Configuration Item (CI)	D&D, Disposal
Disposal, detoxification	Hardware CI	D&D, Detoxification
Disposal, disassembly	Hardware CI	D&D, De-installation
Emergency response deployment	System Test, DT&E or OT&E	Indirect Support, Installation
Emergency response force development	System Test, DT&E or OT&E	Indirect Support, Installation
Facility construction	Industrial facilities, Test Facilities, or Training Facilities	Indirect Support, Installation
Facility modification	Industrial facilities, Test facilities, or Training facilities	Indirect Support, Installation
Hazardous materials procurement	Hardware CI	Sustaining Support, Recurring Investment
Insurance	SE/PM or against specific CI	Sustaining Support, Other
Labeling	Data, Support Data	Sustaining Support, Engineering
Labor to manage ESH programs	SE/PM	Indirect Support, Personnel and Installation
Legal, claims	SE/PM	Indirect Support, Installation
Legal, penalties and fines	SE/PM	Indirect Support, Installation
Legal, review of plans	SE/PM	Indirect Support, Personnel
Lost duty time	SE/PM	Mission Personnel
Lost productivity due to personnel protection requirements	SE/PM	Mission Personnel
Manifesting	Activity for which transportation required	Unit/Depot Maintenance, Other
Material handling, specialized equipment	Peculiar Support Equipment	Sustaining Support, Support Equipment Replacement
Medical examinations	Test and Evaluation Support	Indirect Support, Personnel
Modeling and simulation	SE/PM	Sustaining Support, Sustaining Engineering
Modifications, Pollution Prevention	Hardware CI	Sustaining Support, Modification Kit
Modifications, Safety	Hardware CI	Sustaining Support, Modification Kit
Permits	SE/PM	Indirect Support, Installation Support
Personnel protective equipment	Peculiar Support Equipment	Sustaining Support, Support Equipment Replacement
Pharmacy distribution systems	Initial Spares and Repair Parts	Unit Level Consumption. Other

Table K-1 (continued).

ESH Cost	Phase 0-III WBS	Phase III/D&D WBS
Plans, Compliance and Safety Program	SE/PM	Sustaining Support, Sustaining Engineering or Contractor Support, Other
Pollution Prevention, Filters	SE/PM, Industrial Facilities, or Hardware CI	Unit Level Support, Other
Pollution Prevention, Incinerators	SE/PM, Industrial Facilities, or Hardware CI	Unit Level Support, Other
Pollution Prevention, Scrubbers	SE/PM, Industrial Facilities, or Hardware CI	Unit Level Support, Other
Preservation, natural/cultural	SE/PM, Industrial Facilities, or Hardware CI	Indirect Support, Installation
Public relations/community image	SE/PM	Indirect Support, Installation
Qualifying vendors/suppliers	Hardware CI	Sustaining Support, Recurring Investment
R&D, alternatives to unacceptable materials	Hardware CI	Sustaining Support, Sustaining Engineering
Record keeping, Safety and Health	SE/PM	Indirect Support, Installation
Record keeping, hazardous material	SE/PM	Indirect Support, Installation
Recycling, collection and separation	Hardware CI	Indirect Support, Installation
Recycling, receipts	Hardware CI	Indirect support, Installation
Release monitoring equipment	Peculiar Support Equipment or Industrial Facilities	Sustaining support, Support Equipment replacement
Release monitoring labor	Hardware CI	Indirect Support, Personnel
Remediation, activities	Hardware CI or System Test	Indirect Support, Installation
Remediation, design	Hardware CI	Sustaining Support, Sustaining Engineering
Reporting	SE/PM	Indirect Support, Installation
Restoration investigations, assessments and studies	SE/PM	Sustaining Support, Other or Contractor Support, Other
Risk, cost of not meeting requirements	SE/PM	Sustaining Support, Sustaining Engineering
Risk, of catastrophic events and safety hazards	SE/PM	Sustaining Support, Sustaining Engineering
Sampling	SE/PM	Indirect and Installation Support
Storage structures/containers, specialized	Storage, Planning and Preparation	Sustaining Support, Other
Supervision and audits	SE/PM	Indirect and Installation Support
Surveys, site	SE/PM	Indirect and Installation Support
Surveys, work	SE/PM	Indirect and Installation Support
Technical support, contractors	SE/PM	Contractor Support, Other
Training classes	Training, Services	Mission Personnel, Operation and Maintenance as required
Training materials	Training, Materials	Mission Personnel, Operation and Maintenance as required

Table K-1 (continued).

ESH Cost	Phase 0-III WBS	Phase III/D&D WBS
Transportation, specialized requirements	Storage, Transfer and Transportation or Hardware CI	Sustaining Support, Other
Water treatment, specialized	Hardware CI or System Test	Indirect Support, Installation

Vita

Captain William H. Kale III was born on [redacted] at Fort Belvior, Virginia. He graduated from Ewing High School in Ewing, New Jersey, in June 1990. He entered undergraduate studies at the Pennsylvania State University at University Park, Pennsylvania, where he graduated with a Bachelor of Architectural Engineering degree in May 1995. He was commissioned through AFROTC Detachment 720 at the Pennsylvania State University.

His first assignment was at Pope AFB, North Carolina, with the 23rd Composite Wing as the Chief of Contract Management. In October 1997, he deployed to Prince Sultan Air Base, Saudi Arabia, as the Deputy Chief of Wing Plans for the 4404th Air Expeditionary Wing. In March 1998, he was assigned to the 65th Air Base Wing at Lajes Field, Azores, Portugal, where he served as the Chief of Construction Management and the Base Architectural Engineer. In August 1999, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology. In January 2001, he completed requirements to become a Professional Engineer. Upon graduation, he will attend Squadron Office School at Maxwell Air Force Base, Alabama, and then be assigned to the 819th RED HORSE Squadron at Malmstrom Air Force Base, Montana.

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14. ABSTRACT

Major Defense Acquisition Programs (MDAP) cost billions of dollars and have 30 to 50 year life spans. Numerous (federal, state, etc.) laws, Environmental Protection Agency regulations, and Executive Orders have driven DoD to develop and implement significant environmental policies within the past ten to fifteen years. Congressional mandate now requires each MDAP to evaluate its environmental life cycle cost (ELCC) to minimize these costs. This research focuses on the current methodologies and models used to predict and calculate the ELCC of a MDAP.

This thesis analyzed the difficulties associated with using ELCC methodologies and models and examined several case studies of organizations that have used ELCC methodologies and models. Environmental cost categories from three DoD organizations were analyzed and benchmarked to develop a standardized work breakdown structure (WBS) for all MDAP. A set of criteria was developed to evaluate ELCC methodologies and models and then applied to three existing DoD ELCC methodologies and models (Army ELCC Methodology, Navy ELCC Model, and National Defense Center of Environmental Excellence Environmental Cost Analysis Methodology).

A recommendation is provided to the Deputy Undersecretary of Defense for Environmental Security to develop a new foundation for MDAP by adopting the three existing DoD ELCC methodologies and models and the standardized environmental WBS. Finally, suggestions are provided to help MDAP overcome common difficulties associated with the implementation and use of ELCC methodologies and models.

15. SUBJECT TERMS

Environment, Life Cycle Cost, Models, Acquisition, Weapon System

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